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Monitoring and Analysis of Vertical Deformation of Palm House Benin City Using Digital Level

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ABSTRACT

Monitoring the integrity of engineering structures such as bridges and tall buildings using geodetic methods cannot be underestimated as they provide information about the health of the structures and their safety aspects as well the safety of the public. This study monitored and analyzed the vertical deformation of Palm House in Benin City using Digital Level. Four reference stations and six monitoring points were used. The digital level was used to determine the orthometric heights of the monitoring points with respect to the reference stations heights. The observations were carried out at six epochs of three months interval and adjusted using least squares adjustment technique to determine the reliability of the adjusted observations and that of the adjusted heights. The vertical displacement magnitudes of the monitoring points were computed using the heights differences between the first and the subsequent epochs observations. The evaluated displacement magnitudes were compared with their corresponding computed 95% confidence intervals to determine the significance of the reported movements. The comparison results showed that the building did not undergo any vertical displacement during the monitoring period. It was recommended that large engineering structures such as high rise buildings, bridges, etc should be monitored at regular basis so as to determine their structural integrity since any vertical displacement of the structure which can cause the structure to collapse and thereby result to loss of lives and properties can be detected by epoch monitoring and appropriate measures can be taken.

Keywords: Deformation Monitoring, Leveling, Orthometric height, Epoch, Analysis.

1. INTRODUCTION

Monitoring the integrity of engineering structures such as bridges and tall buildings using geodetic methods cannot be underestimated as they provide information about the health of the structures and their safety aspects as well the safety of the public. As it is well known, engineering structures are subject of deformation due to factors such as changes of ground water level, tectonic phenomena and human activities (Erol et al, 2005). New and existing buildings can be affected by daily movement (solar effects, heavy rainfalls), long period movements (settlement) and dynamic movements (resonance, wind and loads). They may also be built in flood or earthquake zones and therefore at risk of being damaged by natural events. Many buildings are aging and their construction materials deteriorating due to time and weather effect. A monitoring system can insure the structural integrity of a building by providing continues deformation data over extended periods of time. This allows appropriate and cost effective maintenance to be conducted (Abdullahi and Yelwa, 2016).

The monitoring surveys serve not only the purpose of giving information on geometrical changes at the surface of the investigated object but become a tool for physical interpretation of the deformation. The role of the monitoring surveys expands into the explanation of causes of unexpected deformation and consequently has impact on the safety and economy as well as environmental effects (Szostak-Chrzanowski et al, 2005 and Abdullahi and Yelwa, 2016).

Any engineered or natural structure, when subjected to loading, undergoes deformation and/or rigid body movements. Once the deformation, its velocity and/or acceleration, exceed critical values, the structure fails. The critical values are determined using failure criteria that are based upon either empirical formulae or principles of continuum mechanics (Chrzanowski et al, 2007). One of the causes of the partial or total degradation of a structure as pointed out by Armesto et al (2008) is the result of stresses that exceed the resistance to flexion, traction or compression of the construction materials. The consequence of an overload is the appearance of fissures, cracks or fractures.

The purpose of a deformation survey is to determine whether or not movement is taking place and subsequently whether the structure is stable and safe. Movement can be further analyzed to see if it is due to seasonal factors, daily variances etc. and then more importantly use the information to determine future movement of the structure (Aghedo, 2016). It is important to measure this movements for the purpose of safety assessment and as well as preventing any disaster in the future (Aziz et al, 2001**)**.

The benefits of deformation monitoring are the improvement of safety by reduction of the risk of structural failure and the refinement of the structural design process for future applications (Ebeling, 2014). It is an important tool for risk management. Policyholders can reduce exposure before and during construction and throughout the lifecycle of the structure and hence decrease the insurance premium. It is also essential to guarantee the stability and structural integrity of large buildings (Lovse et al., 1995 and Ebeling, 2014).

Geometric levelling is the oldest method of geodetic surveying, used to measure differences of elevations between two or more points at the Earth's surface. Experience has shown geometric levelling to be a reliable and very precise vertical displacement measurement method. Modern electronic levels, with automatic reading and recording, have significantly improved geometric levelling operational performances (Henriques and Casaca, 2007 and Vintilă et al, 2014). For high precision geometric levelling, digital levels should be used. Those levels are automatic levels with a system of digital image processing that allows automatic reading from a special rod, coded bar, and electronic recording. This way all the errors caused by man reading and by manual recording are eliminated and also the speed of levelling increases.

The aim of the study is to monitor Palm House (high rise building) in Benin City by carrying out survey observations (levelling) and rigorous analysis with a view of detecting any vertical displacement of the building. Its objectives are:

1. To carry out levelling at 6 different epochs at interval of three months and processing of the observations to determine the heights of the monitoring network points.

2. To carry out least squares adjustment and statistical analysis on the observations so as to determine the reliability as well as the precision, accuracy and uncertainty of the adjusted observations and those of the adjusted heights.

3. To determine the magnitudes and confidence intervals at 95% confidence level of the vertical displacements of the monitoring points and comparing the determined displacements magnitudes with their corresponding confidence intervals to determine if the displacements are significant or not.

The monitored building was Palm House (Figure 1). It is one of the Edo State Secretariat buildings in Benin City. It is a high rise building located along Benin Sapele Road in Oredo Local Government Area of Edo State. The building is 45m in length, 15m in breadth and 35m in height. It was commissioned by Brigadier Christopher Oluwole Rotimi, the then Military Governor of the Western State of Nigeria on Saturday 10th February, 1973. It is an eleven story building which consists of various ministries and offices. The study area lies between latitudes 06^{0} 18' 38"N and 06^{0} 19' 29"N and longitudes 05^{0} 37' 24"E and 05^{0} 37' 38"E. Figures 2a to c show the maps of the study area.

Figure 1: Palm House, Benin City

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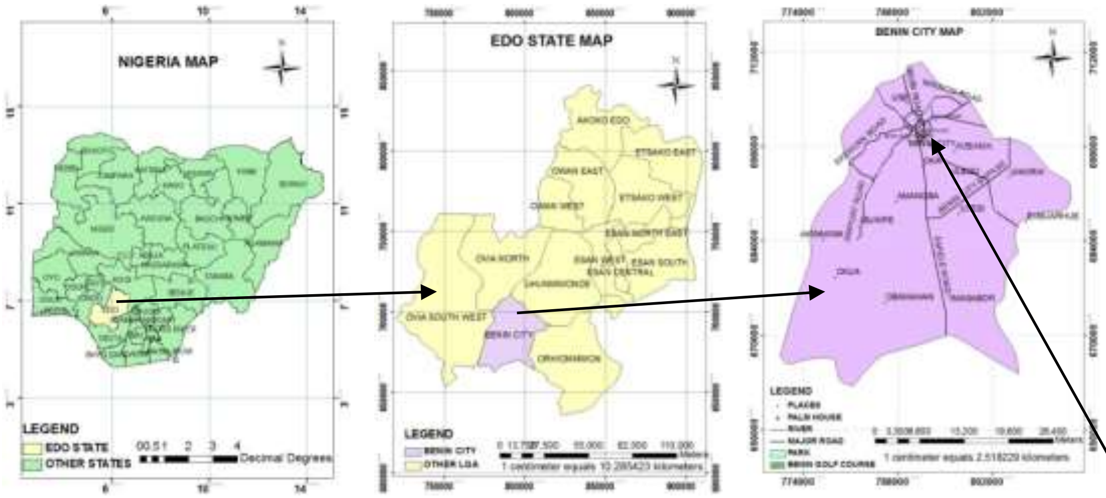

Figure 2a: Map of Nigeria Showing Edo State. **Figure 2b: Map of Edo State Showing Benin City** **Figure 2c: Map of Benin City Showing Study Area**

Source: Ministry of Lands and Surveys, Benin City

Study Area

This study was limited to the monitoring of Palm House (high rise building) in Benin City. The scope of the study is:

i. Marking out of monitoring points (studs) on the building.

ii. Establishment of reference points (stations) on stable grounds or platforms round the building using DGPS.

iii. Determination of the orthometric heights of the reference stations using differential levelling.

iv. Carrying out levelling in different epochs on the building (monitoring points).

v. Least squares adjustment and statistical analysis of the levelling data (orthometric heights).

vi. Evaluation of the vertical displacements magnitudes between the first epoch and the subsequent epochs observations/levelling.

vii Evaluation of the vertical displacements confidence intervals at 95% confidence level.

viii. Evaluation of significance of the computed displacements magnitudes between the first epoch and the subsequent epochs observations by comparing the computed displacements magnitudes with their corresponding confidence intervals to determine if the reported movements were actual movements of the structure or not.

1.1 Least Squares Adjustments by Observation Equation Method

The functional relationship between the adjusted observations and the adjusted parameters is given as (Ono et al, 2014):

$$L_a = F(X_a) \quad (1)$$

Where, L_a = adjusted vector of observations and X_a = adjusted station coordinates. Equation (1) is linear function and the general observation equation model was obtained. To make the matrix expression for performing least squares adjustment, analogy will be made with the systematic procedures. The system of observation equations is presented by matrix notation as (Mishima and Endo 2002):

$$V = AX - L \quad (2)$$

where,

A = Design Matrix

X = Vector of Unknowns

L = Calculated Values (lo) Minus Observed Values (l_b)

V = Residual Matrix

That is,

$$\underset{V}{\begin{pmatrix} v_1 \\ v_2 \\ \dots \\ v_m \end{pmatrix}} = \underset{A}{\begin{pmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{pmatrix}} \underset{X}{\begin{pmatrix} x_1 \\ x_2 \\ \dots \\ x_n \end{pmatrix}} - \underset{L}{\begin{pmatrix} l_1 \\ l_2 \\ \dots \\ l_m \end{pmatrix}} \quad (3)$$

Estimated parameter

$$X = (N)^{-1}(t) \quad (4)$$

Where,

$N = (A^T WA) =$ Normal Matrix

$t = (A^T WL)$

$N^{-1} = (A^T WA)^{-1} = Q_{XX}$

$X = (A^T WA)^{-1}(A^T WL)$ = Estimate

W = Weighted Matrix

The models for the computation of the a posteriori variance and a posteriori standard error as given by Ameh (2013) are:

A Posteriori Variance ($\hat{\sigma}_o^2$) $= \dfrac{V^T WV}{m-n} = \dfrac{V^T WV}{r}$ (5)

A Posteriori Standard Error ($\hat{\sigma}_o$) $= \sqrt{\dfrac{V^T WV}{m-n}} = \sqrt{\dfrac{V^T WV}{r}}$ (6)

Where,

m - *n* = *r* = Degree of freedom

The model for the computation of the standard error of the adjusted parameters is given as (Ameh, 2013):

$$\hat{\sigma}_{xi} = \hat{\sigma}_{\circ}\sqrt{Q_{nn}} = \sqrt{\hat{\sigma}_o^2 Q_{nn}} \quad (7)$$

Where,

Q_{nn} is a diagonal element of the inverse of the normal matrix (N^{-1}).

1.2 Computation of Displacement Magnitude

Once the adjustment of observations is completed, object point displacement is computed as the difference in coordinated/heights between the measurement epochs as given in Ehiorobo and Ehigiator, (2011) as:

$$\begin{Bmatrix} x_j^{k+1} - x_i^k = dx \\ y_j^{k+1} - y_i^k = dy \\ z_j^{k+1} - z_i^k = dz \end{Bmatrix} \quad (8)$$

where,

$x_j^{k+1}, y_j^{k+1}, z_j^{k+1}$ = coordinates of last epoch

x_i^k, y_i^k, z_i^k = coordinates of preceding epoch

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Vertical movement (*dH*) is computed for each object (monitoring) point as

$$dH = \sqrt{\left(z_j^{k+1} - z_i^k\right)^2} = \sqrt{(dz)^2} \tag{9}$$

1.3 Deformation Analysis

Deformation modelling or analysis is done to determine whether point displacements are significant. To determine the significant of points displacements, the computed displacements are compared with their corresponding 95% confidence intervals (Bird, 2009).

If the magnitude of the displacement of a point *j* is classified D_j and the maximum dimension of combined 95% confidence ellipse for point *j* is designated E_j, then, if $|D_j| < E_j$ we conclude that no movement has occurred in point j but rather the difference observed is as a result of measurement error. But if on the other hand $|D_j| > E_j$ then we conclude that point movement (deformation) has occurred (Ehiorobo and Ehigiator, 2011).

$|D_j|$ and E_j are computed as:

$$|D_j| = \sqrt{\left(z_j^{k+1} - z_i^k\right)^2} \tag{10}$$

$$E_j = 1.96\sqrt{(m_{\Delta j}^{k+1})^2 + (m_{\Delta j}^k)^2} = 1.96\sqrt{M} \tag{11}$$

where,

$$M = (m_{\Delta j}^{k+1})^2 + (m_{\Delta j}^k)^2$$

$M = (m_{\Delta j}^{k+1})$ - standard error in position for the K+1 epoch and

$= (m_{\Delta j}^k)$ - standard error in position for the previous epoch k.

The extract of the levelling observation equations and the matrix form of the equations using least squares model are respectively equations (12) and (13).

$$\begin{aligned}
E &= A + \Delta_{AE} + V_{\Delta AE} \\
F &= A + \Delta_{AF} + V_{\Delta AF} \\
G &= A + \Delta_{AG} + V_{\Delta AG} \\
J &= A + \Delta_{AJ} + V_{\Delta AJ} \\
E &= B + \Delta_{BE} + V_{\Delta BE} \\
F &= B + \Delta_{BF} + V_{\Delta BF}
\end{aligned} \tag{12}$$

$$\begin{pmatrix} V_{\Delta AE} \\ V_{\Delta AF} \\ V_{\Delta AG} \\ V_{\Delta AJ} \\ V_{\Delta BE} \\ V_{\Delta BF} \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} E \\ F \\ G \\ H \\ I \\ J \end{pmatrix} + \begin{pmatrix} A + \Delta_{AE} \\ A + \Delta_{AF} \\ A + \Delta_{AG} \\ A + \Delta_{AJ} \\ B + \Delta_{BE} \\ B + \Delta_{BF} \end{pmatrix} \tag{13}$$

2. METHODOLOGY

The methodology involved the following stages namely: data acquisition, data processing, data analysis and presentation. Figure 3 shows the flowchart of the adopted methodology.

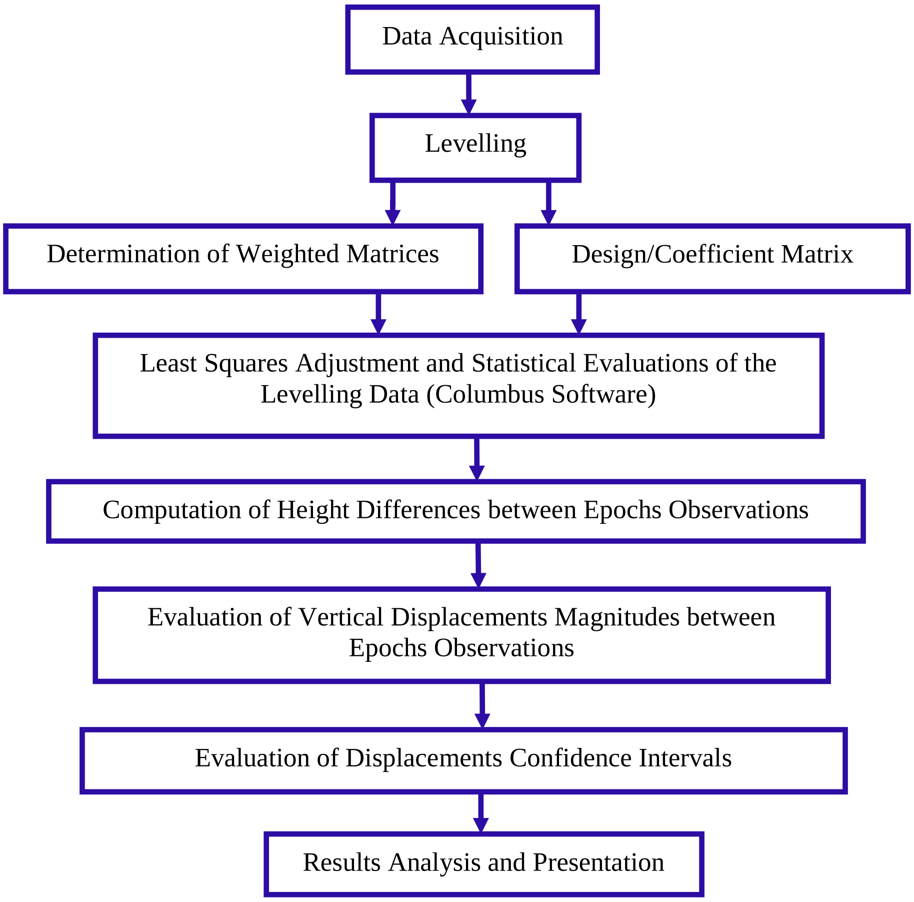

Fig. 3: Flowchart of the Adopted Methodology

2.1 Method of Data Acquisition

2.1.1 Reconnaissance

Prior to the observations, the study area was visited to choose suitable points for reference stations on stable grounds outside the building and to mark out monitoring points on the building walls. The monitoring points on the building walls were about 0.3m above ground level so that levelling staff could be held on them during levelling/observation. The marked monitoring points were made permanent by driving in concrete nails at the marked points. Benchmarks were also located and their heights were obtained from the Edo State Ministry of Lands and Surveys, Benin City.

2.1.2 Monumentation

Pre-cast Property Beacons with dimensions 35cm x 35cm x75cm were emplaced at the four chosen reference points. Each of the beacons was capped with a mixture of cement, sand and water. During this process, the centre of each of the beacons was marked and a number template was engraved on them.

2.1.3 Procedure for Spirit/Differential Levelling

Prior to the observation of the monitoring points, the rectangular coordinates and orthometric heights of the reference stations (A, B, C and D) were respectively determined using CHC900 Dual frequency DGPS receivers and Sokkia SDL50 digital level with respect to control station (FGPEDY06) and benchmark (BC/BM03). The levelling of the monitoring points was divided into two loops (Figure 4), the first loop started from BC/BM03 to reference station C and closed back on BC/BM03 while the second loop started from reference station C and closed back to reference station C. Having determined the coordinates and orthometric

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heights of the reference stations, the digital level was used to determine the orthometric heights of the monitoring points (E, F, G, H, I and J) at six different epochs of three months interval. The first to the sixth epoch observations were respectively taken in March, 2016; June, 2016; September, 2016; December, 2016; March, 2017 and June, 2017. All the observations were taken in the morning hours. Figure 5 shows the levelling network.

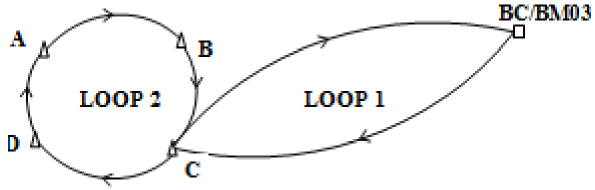

Figure 4: Reference Stations Leveling Loops

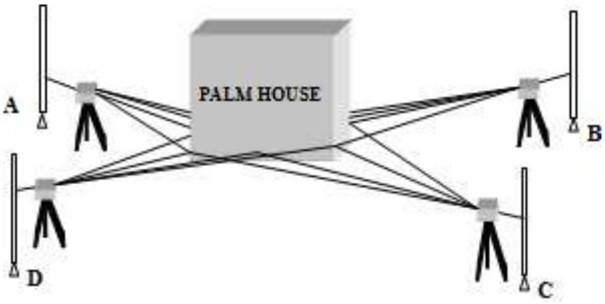

Figure 5: Levelling Network

2.2 Data Processing Procedure

2.2.1 Processing of the Leveling Data

The levelling data, reduced orthometric heights and height differences determined from the spirit/differential levelling using the digital level were typed in Microsoft Excel 2007 spreadsheet and saved in a computer folder.

2.2.2 Least Squares Adjustment of the Processed Heights

The least squares adjustment of the observations/levelling was carried out using Columbus software so as to determine the reliability as well as the precision, accuracy and uncertainty of the adjusted observations and those of the adjusted parameters/heights. The processed levelling data (orthometric heights) were adjusted using equations (3) and (4). The weights of the levelling measurements were determined by finding the inverse of the lengths of the levelling lines while their standard errors were computed from the determined weights. The design matrix (A), observation matrix (L), residual matrix (V), matrix of unknown (X) and weight matrix (W) of the adjusted levelling data were respectively 16 x 6, 16 x 1, 16 x 1, 6 x 1 and 16 x 16 matrices. The a posteriori variances, a posteriori standard errors and the standard errors of the adjusted heights were respectively determined using equations (5), (6) and (7). The adjustment was done with Columbus 3.8 software. Also evaluated using Columbus 3.8 software, were redundancy number, standardized residuals, residual rejection constant (tau statistics) and heights confidence intervals. The heights confidence intervals were scaled at 95% confidence level. Figure 6 shows the adjusted network of the first epoch levelling.

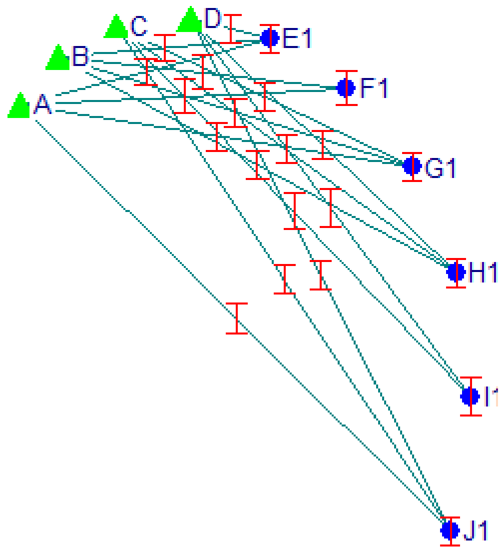

Figure 6: Adjusted Network of the First Epoch Leveling

2.2.3 Deduction of Points Vertical Displacements and their Respective Confidence Intervals

The first epoch observations were used as reference observations such that the subsequent epochs observations were compared with them. Using the first epoch observations as reference observations implies that there were three, six, nine twelve and fifteen months intervals. The differences in heights between the first and the subsequent epochs adjusted heights and their respective magnitudes were respectively determined using equations (8) and (9) while their respective confidence intervals at 95% confidence level were determined using equations (11). The computed displacements magnitudes were compared with the computed confidence interval to determine if the computed displacements were significant or not.

2.3 Results Analysis

Table 1 presents known and observed heights of the closing stations. The observed orthometric heights were seen to be in good shape as shown by the differences between the observed and the known heights of the closing stations of each of the two levelling loops and the ability to reproduce the height of each monitoring point from other reference stations. From table 1, the closing error for the first loop was 0.0057m while that of the second loop was 0.0005m which were within millimetres standard. The results were accepted as the closing errors of the two loops were within millimetres standard and as the orthometric height of each of the monitoring points was able to be reproduced from not less than three reference stations. The high accuracy of the levelling was as a result of the fairly flat topography of the study area, the observer's know-how and equipment used.

Table 1: Known and Observed Heights of the Closing Stations

Station	Description	$H_{(known)}$ (m)	$H_{(observed)}$ (m)	ΔH (m)
BC/BM03	Starting and Closing Station	54.0260	54.0203	0.0057
C	Starting and Closing Station	52.1643	52.1638	0.0005

2.3.1 Analysis of the Adjusted Levelling Results Using Least Squares Technique

The a posteriori variances of the first to the sixth epoch levelling were respectively 0.0000037164m, 0.0000038406m, 0.0000037923m, 0.0000036267m, 0.0000035372m and 0.0000036312m while their respective a posteriori standard errors were 0.0019278070m, 0.0019597430m, 0.0019473700m, 0.0019043800m, 0.0018807360m and 0.0019055590m which show the high precision and accuracy of the adjusted observations. The maximum standard errors of the first to the sixth epoch adjusted heights were respectively 0.0120462, 0.0111885m, 0.0121685m, 0.0118998m, 0.0117522m, and 0.0119072m which show the high accuracy of the adjusted heights. The minimum and the average redundancy numbers were respectively 0.4287 and 0.625 which implies that the variances of the adjusted observations were closed to zero which in turn show the high precision of the adjusted observations. The computed standardized residuals of the six epochs observations/levelling were all less than their respective standardized residual rejection constants which implies that there were no gross errors or outliers hence, none of the observations was rejected. Also, the height confidence intervals of the adjusted orthometric heights of the monitoring points and the relative confidence intervals between the adjusted monitoring points heights and the reference stations heights were computed and plotted at 95% confidence level to determine and present graphically the accuracy of the adjusted height. The maximum confidence intervals of the first to the sixth epochs adjusted heights were respectively 0.023603m, 0.0226232m, 0.0238426m, 0.023316m, 0.023027m and 0.023331m which show the high accuracy of the adjusted heights.

2.3.2 Comparison between the Vertical Displacements Magnitudes and their Corresponding 95% Confidence Intervals

Table 2 and Figure 7 present the vertical displacements magnitudes of the monitoring points and their corresponding confidence intervals at 95% confidence level. The vertical displacements magnitudes of the monitoring points/building at three, six, nine, twelve and fifteen months intervals were computed and compared with their corresponding confidence intervals at 95% confidence level to determine if the computed displacements were actual movements of the structure (significant) or they were as a result of measurement errors. It can be seen from table 2 and figure 7 that the evaluated displacements magnitudes were all less than their corresponding confidence intervals showing that the building did not undergo any vertical displacement during the period of monitoring.

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Table 2: Comparison of the Vertical Displacements Magnitudes with their Corresponding Confidence Intervals

MONITORING POINT		E	F	G	H	I	J
B/W 1ST & 2nd EPOCHS	MAG6NITUDE SQRT((ΔHT)^2) (m)	0.0003973	0.0000999	0.0001727	0.0008375	0.0028527	0.0002430
	1.96*(SQRT(M)) (m)	0.0252411	0.0307612	0.0251137	0.0241149	0.0313804	0.0256615
	DIFFERENCE (m)	0.0248438	0.0306613	0.0249410	0.0232774	0.0285277	0.0254185
B/W 1ST & 3rd EPOCHS	MAGNITUDE SQRT((ΔHT)^2) (m)	0.0006723	0.0008573	0.0008740	0.0010974	0.0009902	0.0013523
	1.96*(SQRT(M)) (m)	0.0252265	0.0320851	0.0257389	0.0230336	0.0308978	0.0239853
	DIFFERENCE (m)	0.0245542	0.0312278	0.0248649	0.0219362	0.0299076	0.0226330
B/W 1ST & 4th EPOCHS	MAGNITUDE SQRT((ΔHT)^2) (m)	0.0001253	0.0000143	0.0000678	0.0000071	0.0000459	0.0002682
	1.96*(SQRT(M)) (m)	0.0243898	0.0303226	0.0247557	0.0253692	0.0331881	0.0254743
	DIFFERENCE (m)	0.0242645	0.0303083	0.0246879	0.0253621	0.0331422	0.0252061
B/W 1ST & 5th EPOCHS	MAGNITUDE SQRT((ΔHT)^2) (m)	0.0000045	0.0001142	0.0001765	0.0001421	0.0000081	0.0001340
	1.96*(SQRT(M)) (m)	0.0242408	0.0301373	0.0246045	0.0252142	0.0329854	0.0249046
	DIFFERENCE (m)	0.0242363	0.0300231	0.0244280	0.0250721	0.0329773	0.0247706
B/W 1ST & 6th EPOCHS	MAGNITUDE SQRT((ΔHT)^2) (m)	0.0001092	0.0001999	0.0001907	0.0002366	0.0002984	0.0000477
	1.96*(SQRT(M)) (m)	0.0243972	0.0303317	0.0247632	0.0248320	0.0330608	0.0250652
	DIFFERENCE (m)	0.0242880	0.0301318	0.0245725	0.0245954	0.0327624	0.0250175

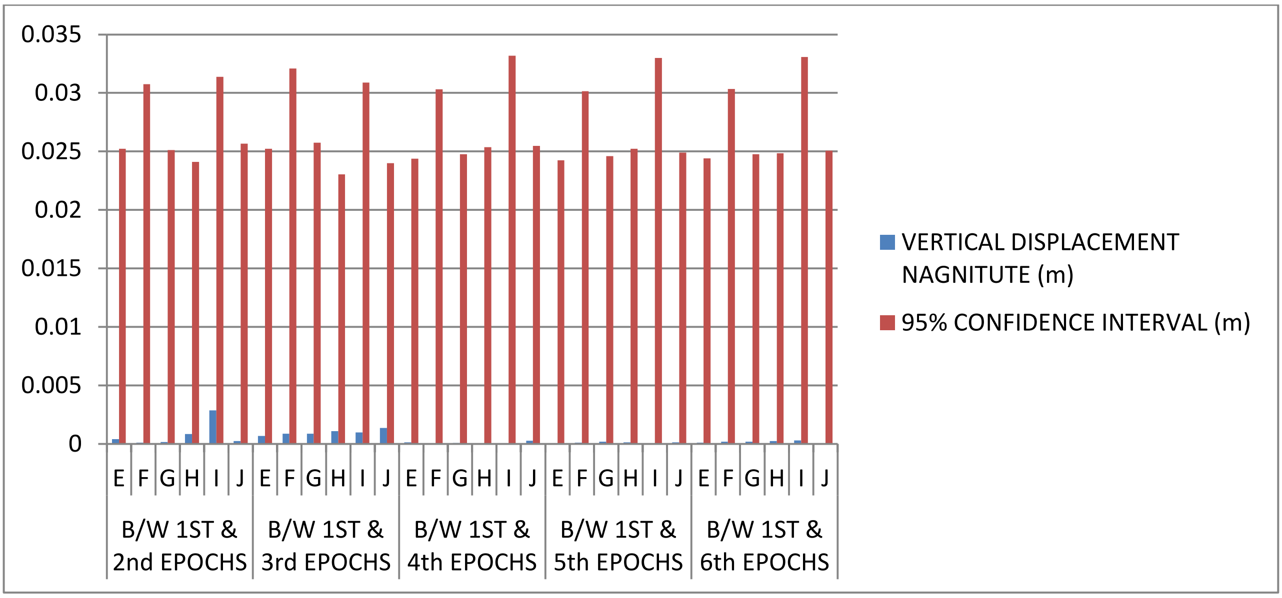

Figure 7: Plot of the Vertical Displacements Magnitudes and their Corresponding Confidence Intervals

3 CONCLUSION

Palm House, Benin City was monitored using Digital Level to determine the structural integrity of the building. Four reference stations and six monitoring points were used altogether. The orthometric heights of the reference stations were determined with respect to a nearby benchmark (BC/BM03) while those of the monitoring points were determined at six epochs of three months interval with respect to the reference stations using Sokkia SDL50 digital level.

The six epochs observations were adjusted with observation equation method of least squares adjustment technique to determine the reliability of the adjusted observations and those of the adjusted parameters/heights using Columbus software. The reliability of the adjusted observations/heights was determined by carrying out some statistical evaluations such as: evaluation of a posteriori variance, a posteriori standard error, and standard errors of the adjusted heights, redundancy number, standardized residual, standardized residual rejection constant (tau statistics), height confidence intervals. The observations were accepted as the results of the statistical evaluations and analysis showed that none of the six epochs observations was rejected and as the precision and accuracy of each of the adjusted epoch observations and those of the adjusted heights were very high.

The adjusted six epochs observations (heights) of each of the monitoring points were compared by finding the differences between the first and the subsequent epochs adjusted heights. The computed differences in heights were used to evaluate the magnitude of displacements of each of the monitoring points between the first and the subsequent epochs observations. The displacement confidence interval of each of the monitoring points was also computed at 95% confidence level and compared with the displacement magnitude of each monitoring point to determine if the reported movements were significant or not. The results of the comparison showed that the reported displacements were not significant, that is, they were as a result of measurement errors since the computed displacements magnitudes were all less than their corresponding confidence intervals, hence, the building did not undergo any vertical displacement during the period of observation.

The results of this study has shown that the building (Palm House) was stable during the period of observation. For this reason, the building is still fit for usage.

4. RECOMMENDATIONS

The monitoring of engineering structures for safety purpose cannot be undermined. Based on the result obtained from this study, the following recommendations were made:

1. That large engineering structures such as high rise buildings, bridges, etc should be monitored at regular basis so as to determine their structural integrity since any movement of the structure which can cause the structure to collapse and thereby result to loss of lives and properties can be detected by epoch monitoring using suitable method and appropriate measures can be taken.

2. That legislation should be put in place stipulating clearly that any large engineering structure which is more than 40 years old except where the life span of the structure is stated and any of such structure that is carrying more loads than it was design to withstand should be investigated or monitored to determine if the structure is still fit for usage, can withstand such excessive loads or undergoing gradual/slow movements.

3. That the other tall building within the secretariat should be investigated/monitored to determine their structural integrity as they were constructed almost the same period that is, they are old

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