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Establishment of Baseline Data for Monitoring Structural Deformation a Case Study of Mechanical Engineering Building, Federal Polytechnic Idah, Nigeria

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***Abstract*-- The concept underlying structural deformation monitoring using various methods had over the years been of interest to civil engineers, structural engineers, surveyors and all other allied environmental-based professionals is aimed at protecting various infrastructures and facilities. This paper thus aims at discussing the establishment of base line data using geodetic survey method to establish the baseline infrastructure. Five control stations were established around the mechanical Engineering building for the purpose of monitoring. The baseline infrastructure was established using the total station (SOKKIA SET 310). Statistical analysis carried out showed that the differences in the mean, standard deviation and variances of the rectangular northing coordinates as compared to the grid equivalent were *0.120m,-0.104m* and *0.111m* respectively. That of the eastings was *0.893m, 0.041m* and *3.83m* respectively. The angular misclosure of the traverse was (*00° 00' 12"*).The linear accuracies of the traverse and that of the grid were *1/79,000* and *1/93,000* respectively. The least squares adjustment gave values of a-priori standard error and variance of (*0.0005032* and *0.0000145*) respectively. The study revealed that the established baseline infrastructure data would in no small measure facilitate the structural deformation monitoring of the mechanical engineering building in particular and other adjourning structures of the polytechnic in general. It is recommended that a network of similar infrastructures be established to enhance effective monitoring of high-rise buildings which is presently on the increase in the polytechnic. This will provide early warning information to avert dangers.**

***Index Terms*— Baseline data, Deformation, Infrastructure, High-rise, Geodetic, least square**

I. INTRODUCTION

Geodetic Control Infrastructure (GCI), which is one of the major topographic reference or base for the measurement and analysis of geodynamic activities, such as ground subsidence and deformation, crustal and tectonic plate movements, earthquake and landslides, erosion and geomorphologic processes, etc, have suffered huge neglect and dilapidation, hence have not commanded 'effective demand' in the choice of services of the Nigerian communities

[1]There are two categories of measuring techniques and instrumentation for monitoring deformation in structures namely geodetic surveys using Global Positioning System (GPS) among others as well as geotechnical measurements by local deformation

[2]Construction of large engineering structures such as high rise buildings and bridges is essential for the development of a nation. However, under excessive loading, such structures are subjected to deformation, potentially causing loss of lives and properties, hence, the safety of these works demands periodic monitoring and depth analysis of their structural behavior, based on a large set of variables that contribute to the deformation

[3]The incessant cases of building collapsing with an attendant loss of lives and properties pre-empt the need for structural monitoring to avert the occurrences of such in the future. The study of earth movement and absolute or relative movement of artificial structures on the earth's surface constitutes one of the aims of geodesy

[4]The major causes of structural failures in buildings have been attributed to poor workmanship, foundation failure, bad design, unexpected loading among others

[5,6] Studies have shown that the Global Positioning System (GPS) technology can be used to monitor deformation in structures

[7,8]It is generally known that the northern part of Nigeria has more stable geophysical structure than the southern part. Nevertheless, the expansive nature of structural failure in Nigeria in recent times can no longer be classified on the basis of geographical partitioning. This is because almost every part of the country has witnessed one form of structural failure or the other. The research question therefore is: Is structural failure over a stable plate like Nigeria a function of only quality of construction and material used?

In other to provide answers to this question, there is need to conduct a geodetic and geotechnical examination on this large engineering structure. The only enablement for this is a stable baseline-based geodetic infrastructure which is presently not available.

The Federal Polytechnic, Idah, is located at Okenya, a rural community in the eastern suburb of Idah town in Nigeria, Idah, being an old river port, lies on the eastern bank of River Niger. It lies between latitude 07^0 06' 48"N' and 08"N of the equator and between Longitude 06^0 46' 25"E of the Greenwich meridian

[8]This paper therefore seeks to establish geodetic baseline data for assessing the stability or otherwise of the Mechanical Engineering Building of the Federal Polytechnic, Idah, Nigeria as shown in Fig.1. This building is the structure under study,

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situated at Campus 1 of the Federal Polytechnic, Idah, Nigeria. It was constructed in 1976 and was commissioned officially in 1986. It is 1.76km long and 20m wide. It housed about twenty structures made up of workshops, staffrooms and classrooms including heavy machineries.

There've been series of construction works in other to meet up with the intended operation of the entire Polytechnic. The series of construction works close to the building prompted the need for the provision of control for monitoring the structure and subsequent monitoring of some of these projects.

The aim of this project is the establishment of baseline data for monitoring structural deformation of the mechanical Engineering building, Federal Polytechnic Idah, Kogi State.

The aim would be achieved through the following objectives:

I. Establishment of second order geodetic controls, outside influence area of the building.
II. To carry-out total station observations on established stations.
III. Application of an online Matrix calculator for the evaluation of the least squares adjustment.

Fig.1 East-West view of Mechanical Engineering Building

II. METHODOLOGY

Data Acquisitions

The SOKKIA SET310 electronic total station was used to directly determine the point coordinates of the stations. A closed traverse was employed in this project. The traverse started from the known point FPI/SVC/001 and closed, fore sighting to control station FPI/SVC/005. The instrument was mounted on station (FPI/SVC/001), centered, leveled and well focused aimed at eliminating parallax. Two targets were mounted each on stations (FPI/SVC/002) and FPI/SVC/005, being the rear and fore stations respectively. The tripods were adequately leveled using the foot screws. The target heights and the instrument height (HI) were measured after which the battery for the instrument was installed and powered on after which observation commenced. The necessary data needed for all the stations where observed and recorded.

Corridor Mapping of the Route:

This aspect of the field work involved the mapping of the details along the route of the Traverses using the Total Station. The Department of Electrical Engineering and workshop buildings were mapped in this respect. The edges of these structures were coordinated using the total station located at respective traverse monitoring stations.

Field Precautions:

The following were adhered to:

(a) The centering and leveling of the total station and the targets were carefully carried out.
(b) Ensured that instrument bubble was always at the center of its run.
(c) Parallax was always cleared for clean bisection.
(d) In order to ensure accurate booking, the booker repeated the values after the observer before finally booking down the values.
(e) Observations under sunny conditions were minimized.

III. RESULTS AND ANALYSES

All observed coordinates of the forward target station were adequately booked as shown on

Table 1: Abstract of obtained Total Station Coordinates

Station From	Nothings (m)	Easting (m)	Height (m)	Station To
	789543.208	256344.373	325.162	FPI/SVC001
FPI/SVC/001	789347.909	256329.835	316.944	FPI/MNS/001
FPI/MNS/001	789301.154	256387.643	317.093	FPI/MNS/002

Data Processing

The coordinates obtained by the Total Station were provisional coordinates .These coordinates are transformed to their ellipsoidal (GRID) equivalent.

Computation of Grid Coordinates:

According to [9], this involved the transformation of the surface Coordinates from the terrain to the Clarke 1880 ellipsoid.

The grid coordinates were computed using the following parameters: The surface coordinates of the stations, the surface bearing and distances between Stations and the heights of the stations. The sample computation of this concept is carried out for traverse line (FPI/SVC/001 to FPI/MNS/001) with the following parameters:

Table 2: Abstract of data used for evaluation of grid coordinates of MNS/001

Stn	N(m)	E (m)	H	φ	λ	H_{sf}	Brg_{sf}
FPI/SVC 001	789543.208	256344.373	325.162	7^0 8' 15"	6^0 47' 42"		
FPI/MNS/ 001	789347.909	256329.835	316.944	7^0 8' 09"	6^0 47 38	195.839	184^0 15' 26"

Hence: H_{mean} =321.053m; φ_{mean}=7^0 8' 12.18"; λ_{mean}= 6^0 47 42.22";

Where: (H_{sf}) is the surface distance and (Brg_{sf}) the surface bearing

The transformation of the surface distances to the ellipsoidal plane basically involved the application of two corrections: The elevation factor and Scale Factor corrections.

Reduction of surface distances to the Grid

- Elevation Correction (E_F)

$$E_F = \frac{\text{Sea Level Distance}}{\text{Ground Distance}} = \frac{R}{R+H} \quad \ldots\ldots\ldots 1$$

Where: R= Mean radius of the earth = 6372km = 6372000m

H = Mean elevation

$$E_F = \frac{637000}{(637321.053)} = 0.999949618$$

The Scale factor correction: The scale factor for the Universal Traverse Mercator Projection System (UTM) was computed using the equation:

$$S_{fc}(p) - S_f(cm)(1 + x^2/2R^2) \ldots\ldots\ldots 2$$

Where:

$S_{fc(p)}$ = Scale factor at the survey station (P)

$S_{f(cm)}$ = Scale factor at the central meridian

X = The East / West distance of the survey station from the central

Meridian (i.e. Mean of the Easting Coordinates of adjacent Survey stations)

R = The Mean Radius of curvature of the Clarke 1880 Ellipsoid

Computation of the mean Radius of curvature of the Clarke 1880 Ellipsoid (R): This is given as:

$$R = \sqrt{RN} \ldots\ldots\ldots 3$$

R = The Mean Radius of curvature of the Clarke 1880 Ellipsoid

The Evaluation of the Earth's Mean Radius (R_M) given as:

$$R_M = \sqrt{(MN)} \ldots\ldots\ldots 4$$

Where: M = Radius of curvature of the Ellipsoid along the Meridian

N = Radius of curvature of the Ellipsoid along the Prime Vertical

But

$$M = \frac{(1-e^2)}{(1-e^2 Sin^2\theta)^{\frac{3}{2}}} \ldots\ldots\ldots 5$$

With: e^2 = eccentricity of the ellipsoid given as:

$$e^2 = \frac{a^2 - b^2}{a^2} \ldots\ldots\ldots 6$$

For Clarke 1880 spheroid:

a: The Semi - Major axis having a value of (6378249.145m)

b: Semi - Minor axis having a value of (6356514.870m)

φ = latitude of a place of observation

Therefore, computing the eccentricity,

$$e^2 = \frac{a^2 - b^2}{a^2} e^2 = \frac{(637849.145)^2 - (6356514.870)^2}{(6378249.145)^2}$$

$$e^2 = 0.006803511$$

Evaluation of (M): Given as:

$$M = \frac{(1-e^2)}{(1-e^2 Sin^2\theta)^{\frac{3}{2}}} \ldots\ldots\ldots 7$$

$$M = \frac{6334854.657}{0.9998435118} = 6335846.142m$$

Evaluation of the value of "N": Given as:

$$N = \frac{a}{(1-e^2 Sin^2\theta)^{\frac{1}{2}}} \ldots\ldots\ldots 8$$

$$N = \frac{6378249.145}{0.999947834}$$

$$= 6378581.887m$$

The Mean Radius of the Earth is evaluated using the formula: Where:

$$R = \sqrt{MN}$$

R=

$$\sqrt{6335846.142} \times 6378581.887$$

$$\gg R = 6357178.103m$$

$$S_{fc(p)} = S_f(cm)(1 + x^2/2R^2) \ldots\ldots\ldots 9$$

$$S_f(cm) = 0.9999;\ x = (256344.373 + 256329.835)/2$$

$$= 256337.104$$

$$S_{fc(p)} = 1 + \frac{256337.104^2}{(2 \times 6357178.103^2)}$$

$S_{fc(p)}$= 1.000712869

The Combined Factor Correction (CF_c) : This correction is given as:

Combined factor Correction (CF_c) =

Elevation factor (E_{fc}) * Scale factor correction ($S_{fc(p)}$)

$$CFc = (0.999949618 \times 1.000712869) = 1.000662451$$

The grid distances (H_{grid}) are computed using the formula:

Grid distance =

$$\textit{Ground distance} \times \textit{Combined factor correction}$$

$$H_{grid} = E_{fc} \times S_{fc\,(p)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 10$$

$$H_{grid} = 195.839 \times 1.000662451$$
$$H_{grid} = 195.969m$$

The reduction of grid bearings to geodetic bearing is carried out by first computing the convergence which is given by the equation:

$$\textit{Convergence Correction } (c'') = (\lambda^0 - \lambda')\, Sin\, \varphi \ \ldots 11$$

Where: λ"= Longitude of the UTM Zone 32 central meridian
(λ^0) =Longitude of point of observation
φ =Latitude of point of observation

$$c'' = (08° \, 30' \, 00'' - 06° \, 47' \, 42.22'') \times sin(07° \, 08' \, 12.18'') = 00° \, 12' \, 42.45''$$

Hence: Geodetic Bearing $= 184° \, 15' \, 26'' + 00° \, 12' \, 42.45''$

Geodetic (Grid) Bearing $= 184° \, 28' \, 09''$

The grid coordinates were computed using the relationships:

(i) $NORTHINGSGRID = NORTHINGS_{SURFACE} \pm \Delta N$ and……12

(ii) $EASTINGS_{GRID}\ EASTINGS_{SURFACE} \pm \Delta E$….13

Where:

$$\Delta N = \textit{Grid distance} \times Cos(\textit{Grid Bearing}) \ldots 14$$

$$\Delta E = \textit{Grid distance} \times Sin(\textit{Grid Bearing}) \ldots 15$$

From appendix 4.0, the evaluated grid distance and bearing for traverse line (FPI/SVC/001 to FPI/MNS/001) are (**195.969m**) and ($184^0 28' 09''$) respectively.
Hence:

$$\Delta N = 195.969 \times Cos(184^0 28' 09'') \gg -195.373m$$

$$\Delta E = 195.969 \times Sin(184^0 28' 09'') \gg -15.270m$$

Thus:

$$NORTHINGSGRID = NORTHINGS_{SURFACE} \pm \Delta N = 789543.208 - 195.373$$

$$NORTHINGSGRID - 789347.835m$$

$$EASTINGS_{GRID} = EASTINGS_{SURFACE} \pm \Delta E = 256344.373 -$$

$$EASTINGS_{GRID:} = 256329.103m$$

Table 3 shows the coordinates obtained from total station traverse and Table 4 shows the evaluated grid coordinates.

Table 3 Rectangular Coordinates obtained from Total Station Traverse.

S/No	Station	Nothings (m)	Easting s(m)	Height (m)
1	FPI/MNS/001	789347.909	256329.835	316.944
2	FPI/MNS/002	789301.154	256387.643	317.093
3	FPI/MNS/003	789256.177	256377.797	315.732
4	FPI/MNS/004	789261.912	256303.445	314.068
5	FPI/MNS/005	789352.019	256282.096	316.499

Table 4: Grid Coordinates.

S/No	Station	Nothings (m)	Easting (m)	Height (m)
1	FPI/MNS/001	789347.813	256329.109	316.944
2	FPI/MNS/002	789300.813	256386.781	317.093
3	FPI/MNS/003	789256.688	256376.750	315.732
4	FPI/MNS/004	789261.875	256302.375	314.068
5	FPI/MNS/005	789352.125	256281.344	316.499

Least Squares Adjustment

In order to evaluate the most probable value of the ellipsoidal coordinates and for the purpose of other analysis, the Least Squares Adjustment technique was carried out using the Observation Equation Model . The software used for the leastsquare adjustment was the Online Matrix Calculator Bluebit software in www.bluebit.gr/matrix-calc/. Table 5 shows the finally adjusted result of the Least Squares estimate.

Table 5 Adjusting Least Squares Estimates

S/NO	NORTHINGS	CORR	$NORTHING_{CORR}$	EASTHINGS	CORR	$EASTHING_{CORR}$
MNS/01	789347.813	+0.001	789347.813	256329.109	-0.000	256329.109
MNS/02	789300.813	-0.001	789300.813	256386.781	+0.000	256386.781
MNS/03	789256.688	+0.000	789256.688	256376.750	-0.014	256376.736
MNS/04	789261.875	-0.018	789261.875	256302.375	-0.019	256302.356
MNS/05	789352.125	+0.023	789352.125	256281.344	+0.038	256281.382

It also shows the correction applied to the grid coordinates as a result of least squares adjustment exercise and the final coordinates which serve as the achieved baseline data. From this research the baseline data for monitoring deformation was established based on adjusted least square estimates in Table 5 and the data so obtained can now be used for other monitoring exercises

Table 6 Required Baseline Data based on adjusted Least Square Estimates.

S/No	Station	Nothings (m)	Easting (m)	Height (m)
1	FPI/MNS/00 1	789347.81 4	256329.10 9	316.94 4
2	FPI/MNS/00 2	789300.81 2	256386.78 1	317.09 3
3	FPI/MNS/00 3	789256.68 8	256376.73 6	315.73 2
4	FPI/MNS/00 4	789261.85 7	256302.35 6	314.06 8
5	FPI/MNS/00 5	789352.14 8	256281.38 2	316.49 9

IV SUMMARY, CONCLUSION AND RECOMMENDATIONS

In summary the baseline infrastructure was established for the structural monitoring of the Mechanical Engineering Building of the Federal Polytechnic, Idah, Nigeria. To achieve this, controls were extended from the school premises to the vicinity of the structure using the surveying techniques of Total Station Traversing. The direct Coordination method was used in the Total Station Traverses. The Corridor mapping of the route was also carried out. In all, five controls were established. These rectangular coordinates were then transformed to their respective ellipsoidal (grid) coordinates.

In conclusion, the control-based baseline infrastructure so established would in no small measure facilitate and ultimately add value to the planning, design and implementation of the structural deformation monitoring of the Mechanical Engineering Building in particular and other adjourning structures of the Institution in general.

The following recommendations have been made in respect of this research:

(i) That a network of similar baseline data infrastructure be established to enhance the effective monitoring of high-rise buildings which are presently on the increase in the Institution

(ii) That taking into due cognizance the ever increasing cases of collapsed buildings, adequate awareness be made by relevant authorities on the need and importance of carrying out deformation surveys/studies of various structures which are culpable of being deformed as a result of tectonic activities of the earth crust.

REFERENCES

[1] Fajemirokun F.A and Nwilo P.C: Determination and stability monitoring by geodetic technique; A case study of the National Theater of the University of Lagos Senate house. A paper presented at the NIS conference held at Uyo, 1997, pages 45-47.

[2] USACE *Structural Deformation Surveying* EM 1110-2-1009. US Army Corps of Engineers 2002. Washington DC.

[3] Richardus, P.. *Project Surveying*. Amsterdam: North Holand Publishing 1997 p29.

[4] Feld, J. and Carper, K.L. Construction Failure. John Wiley and Sons. 1997

[5] Collacott, R.A. *Structural Integrity Monitoring*. Chapman and Hall. 1985 Pp1-5

[6] Ogaja, G.; Li, X and Rizos, C. Advances in Structural Monitoring with Global Positioning System Technology: 1997 – 2006 *Journal of Applied Geodesy* 2007 Vol 1 (3) pp 171-179.

[7] Knecht, A. and Manetti, L. Using GPS in Structural Health Monitoring. SPIE's 8th Annual International Symposium on Smart Structures and Materials. 4th – 8th March 2001.

[8] OSGOF Topographical Map of Idah, NE Quadrant, Scale 1:100,000, Office of the Surveyor-General of the Federation. Abuja, Nigeria 2007

[9] Kavanagh, B. F; *Surveying with Construction Applications* 6th Edition, Upper Saddle River, New Jersey Colombos, Ohio 1989