Establishment of a Geodetic Baseline for verification of length measurement in Federal University of Technology Minna, Nigeria

GBEDU, Adamu Mohammed, Opaluwa, Y. D, Zitta, N., and Adeniyi, Gbenga

Department of Surveying and Geoinformatics, Federal University of Technology Minna, Nigeria

Corresponding Author: adamu.gbedu@futminna.edu.ng

Abstract

A geodetic baseline is a set of pillars, ranging from few to more than 10 at distance varying from 10 of meters to one kilometer. The baseline is a reference line for conducting surveys, for the triangulation network, calibration of Electronic Distance Measuring (EDM) Instruments detecting the errors, performance, and the correction of the instruments. Thus, this study was designed to describe the establishment procedure and use of the facility for verification of electro- optical distance meters in Federal University of Technology, Minna). The design and establishment of the geodetic baseline consisted of five concrete pillars with forced centering arrangements that enabled the determination of all instrument errors to an appropriate level of precision. The reference points were set up and the absolute distances between the points were determined with a standard deviation of 0.03mm using the Leica Absolute Tracker AT401. The baseline was also used for testing the distance meters of three total stations, by comparing the actual lengths between the pillars ("true values") with the measured lengths. The points were placed on 0m, 30.5, 86.5, 158, and the last point placed on 195m from the initial point. After establishment of the geodetic baseline, three different instruments (Sokkia 530R3, Sokkia 630R, and Wild DI 10) were calibrated on three different dates, ensuring similar metrological conditions, to have precise distance measurements. The results obtained from the calibration showed that the readings acquired on these instruments were accurate and approximately containing error of 0.55 millimeters

Keywords: EDM, geodetic baseline, calibration, triangulation, concrete pillars

Établissement d'une ligne de base géodésique pour la vérification de la mesure de longueur à l'Université fédérale de technologie de Minna, Nigéria

Résumé

Une ligne de base géodésique est un ensemble de piliers, allant de quelques-uns à plus de 10, à une distance variant de 10 mètres à un kilomètre. La ligne de base sert de ligne de référence pour effectuer des levés, pour le réseau de triangulation, l'étalonnage des instruments de mesure de distance électronique (MDE), détecter les erreurs, la performance et la correction des instruments. Ainsi, cette étude a été conçue pour décrire la procédure d'établissement et l'utilisation de la structure pour la vérification des mètres de distance électro-optiques à l'Université fédérale de technologie de Minna. La conception et l'établissement de la ligne de base géodésique ont consisté en cinq piliers en béton avec des arrangements de centrage forcé permettant de déterminer toutes les erreurs des instruments avec un niveau de précision approprié. Les points de référence ont été installés et les distances absolues entre les points ont *été déterminées avec un écart type de 0,03 mm à l'aide du Leica Absolute Tracker AT401. La ligne de base a également été utilisée pour tester les mètres de distance de trois stations totales, en comparant les longueurs réelles entre les piliers (« valeurs réelles ») avec les longueurs mesurées. Les points ont été placés à 0 m, 30,5 m, 86,5 m, 158 m et le dernier point a été placé à 195 m du point initial. Après l'établissement de la ligne de base géodésique, trois instruments différents (Sokkia 530R3, Sokkia 630R et Wild DI 10) ont été étalonnés à trois dates différentes, en assurant des conditions métrologiques similaires, pour obtenir des mesures de distance précises. Les résultats obtenus lors de l'étalonnage ont montré que les lectures acquises sur ces instruments étaient précises et contenaient une erreur d'environ 0,55 millimètre.*

Mots-clés : MDE, ligne de base géodésique, étalonnage, triangulation, piliers en béton

ملخص

خط الأساس الجيوديسي هو مجموعة من الأعمدة، تتراوح من عدد قليل إلى أكثر من 10 على مسافة تتراوح من 10 أمتار إلى كيلومتر واحد. خط الأساس هو خط مرجعي لإجراء الدراسات الاستقصائية، لشبكة التثليث، ومعايرة أجهزة قياس المسافات الإلكترونية (EDM) للكشف عن الأخطاء والأداء وتصحيح الأدوات. وبالتالي، تم تصميم هذه الدراسة لوصف إجراءات إنشاء واستخدام المرفق للتحقق من عدادات المسافات الكهربائية البصرية في الجامعة الفيدرالية للتكنولوجيا، مينا). يتألف تصميم وإنشاء خط الأساس الجيوديسي من خمس ركائز ملموسة مع ترتيبات التركيز القسري التي مكنت من تحديد جميع أخطاء الأجهزة إلى مستوى مناسب من الدقة. تم إعداد النقاط المرجعية وتم تحديد المسافات المطلقة بين النقاط بانحراف معياري قدره 0.03 ملم باستخدام AT401 Leica Absolute Tracker. تم استخدام خط الأساس أيضًا لاختبار عدادات المسافة لثلاث محطات إجمالية، من خلال مقارنة الأطوال الفعلية بين الركائز («القيم الحقيقية») مع الأطوال المقاسة. تم وضع النقاط على 0 م، 30.5، 86.5، 158، وآخر نقطة وضعت على 195 م من النقطة الأولية. بعد إنشاء خط الأساس الجيوديسي، تمت معايرة ثلاثة أجهزة مختلفة (سوكيا R3530، وسوكيا R630، وويلد دي آي 10) في ثلاثة تواريخ مختلفة، مما يضمن ظروفًا مترولوجية مماثلة، للحصول على قياسات دقيقة للمسافات. أظهرت النتائج التي تم الحصول عليها من المعايرة أن القراءات المكتسبة على هذه الأدوات كانت دقيقة وتحتوي تقريبًا على خطأ قدره 0.55 ملم.

الكلمات الرئيسية: EDM، خط الأساس الجيوديسي، المعايرة، التثليث، الركائز الخرسانية.

Introduction

A geodetic baseline is a set of pillars, ranging from few to more than ten, at distance varying from ten of meters to one kilometer. The Home test field calibration baseline is a reference line for conducting surveys, for triangulation network, trilateration and for calibration of Electronic Distance Measuring (EDMI) Instruments. The design and formation of geodetic baseline will aid in correction and standardization of Electronic Distance Measuring (EDM) Instruments with an appropriate level of precision (Braun, *et al*., 2014; Zakari and Aliyu, 2014).

As more surveyors acquired EDMI, the surveying profession became concerned about the accuracy of their measurements. It has been shown that whereas accuracies attributed by the manufacturers to the instruments are reliable, errors in the observations, which are often systematic, can result from normal usage due to a reduction in the efficiency of electronic and mechanical components. Periodic maintenance, preferably by the manufacturer or a designated representative, is required to minimize such errors. It is equally important to verify the instrument constant and evaluate the measuring accuracy at more frequent intervals in conformity with

International standard Organization (Rüeger, 1990; ISO 17123-4 -Optics and optical instruments, 2012).

With the development of surveying, mapping and development of Geographic Information System (GIS), databases in public and private sector organization, institutions of higher learnings, the establishment of a five point's base pillars placed at 0m, 30.5, 86.5, 158, and 195m from the initial point A is immensely important. Moreover it will be a constant learning resource for researchers working with various surveying equipment and techniques.

Materials and methods

The establishment of a geodetic baseline requires first site selection and the clearance of all the wild bushes and scrubs so that the site can be easily accessible. This followed by the location where the base pillars would be formed is selected with the help of surveying by total station and special prism reflector(construction of the calibration pillars bays). On completion of calibration bays, three different EDM instrument (SOKKIA 530R3, SOKKIA 630R, and Wild DI 10

) is set up at a particular point which is known as the first point and considered to be as ”0m‟ point for verification of total stations. The sequence of the field procedures for establishment of geodetic baseline in FUTMINNA is as follows:

The lack of geodetics calibration baseline in FUTMINNA campus posed a challenge to provide traceability of length for electro-optical equipment with; total stations, reflector less total stations, laser scanners (Arabatzi *et al*., 2017; Japhet *et al*., 2021; Pagounis *et al*., 2022; Florian *et a*l., 2023). Hence, the aim of this research work was to describe the processes involved in the design and establishment of a geodetic calibration baseline in FUTMINNA.

Establishment of a control baseline for length measurements

For the establishment of the geodetic baseline, the first important step was site selection and its clearance of all the wild bushes and scrubs so that the site can be easily accessible. After the site is being cleared up, the location where the base pillars would be formed is selected with the help of surveying by total station (Leica Absolute Tracker AT401) and special prism reflector. For this purpose, Figure 1, depicts the location of geodetic baseline, at Federal University of Technology, Minna on 09° 32' 30.46"N, 06°026'14.37"E at the top left, 09°0 31'15.84"N, 06°027' 20."67E at the bottom of the longitude and latitude respectively.

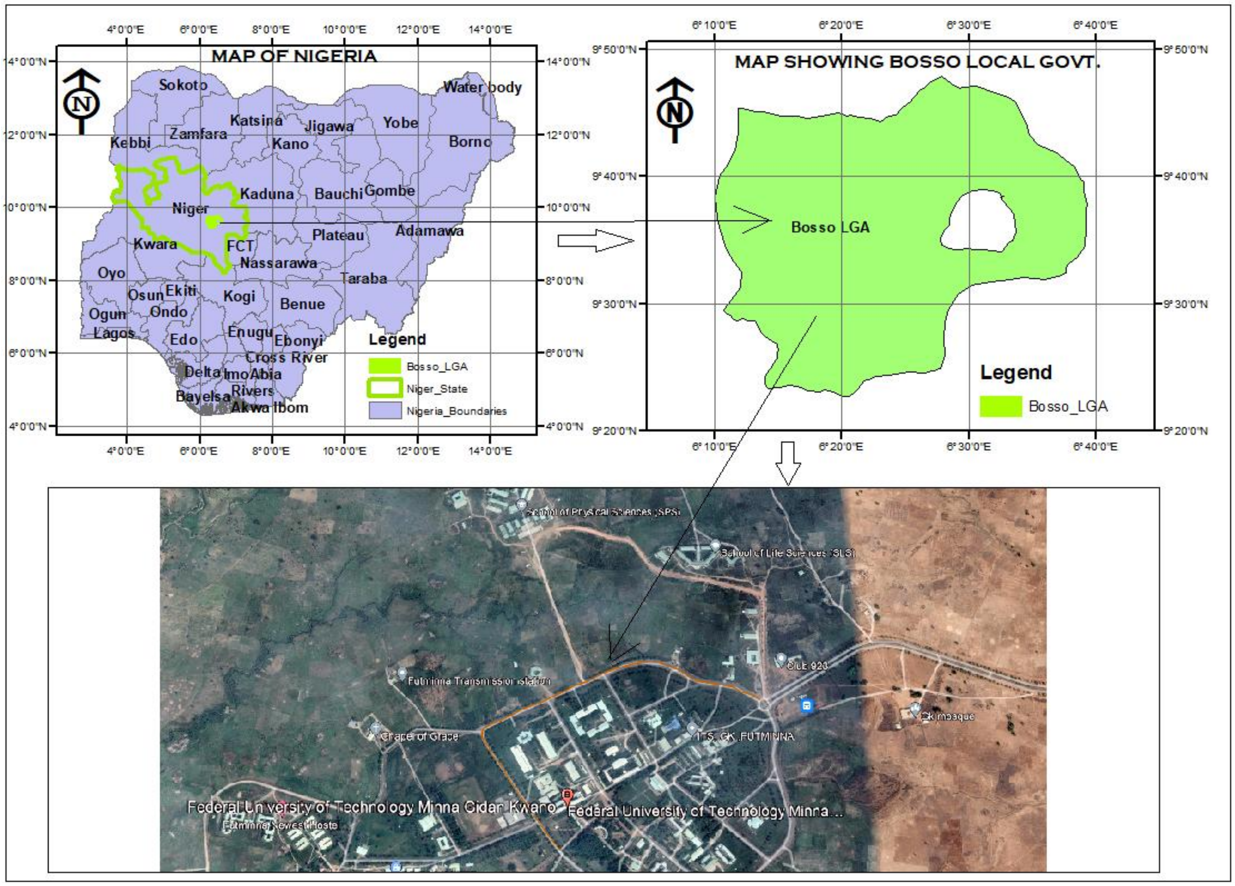

Figure 1: Location of geodetic baseline at Federal University of Technology, Minna (Gidan Kwanu- campus).

The instrument was set up at a particular point which was known as the first point and considered to be on chainage 0 .000m" point. For the selection of the points, firstly, instrument was placed on the initial point i.e. point of survey. Then, the rest of the points are acquired through this initial point. A total of five points were established on a straight line configuration. The points were placed on 0m, 30.5, 86.5, 158, and the last point placed on 195m from the initial point. To ensure the authenticity of the points taken, a back and forth readings were acquired (Buga *et al*., 2011).

Construction of the calibration Pillars (Bays)

After the selection of the site, the construction process took place. It was a requisite to dig up the 2 by 2 feet hole. Once the hole was dug then the second stage was to place the steel rods into the exact position of the points observed at the earlier stage. There were two different lengths of the steel rods attained on 1 m long and the other is was 2m long. In the beginning the 1m long is was positioned exactly where the point was placed which was then verified by the total station. After verifying the location, then the 2 m long rod was tied up in such a way that the combined length of the rods was 4.5 feet above the ground.

Once it ensured that the steel rods were placed on a right place then the crushed brick were ground by pressing and squeezing in the base to make the foundation of the pillars.

After the foundation was prepared, smoothened and levelled, the cement pipe was placed carefully on the location before the concrete filling gets dry and confirming that the steel plates were not displaced.

Subsequently, the concrete was filled after placing the cement pipe so that pipe was fixed into the location. The pillars were constructed keeping in view the standard height of 4.5 feet. To make available the use of pillars for every height, the 6 inches base was constructed so that the height of the pillar become 4 feet above the ground instead of 4.5 feet.

When the process of placement and filling of the cement pipe was done, then followed by a very important phase of the baseline establishment, which is the placement of the fabricated steel plates. Fabricated steel plates were the plates with forced centering arrangement in order to set up instrument easily (Braun *et al.,* 2014). Steel plates are placed very carefully and to confirm that these plates are placed on the right place. The prism reflector was placed onto it and then the readings were acquired.

Verification of total stations using, SOKKIA 530R3, SOKKIA 630R, and Wild DI 10

The next important stage was the utilization of the geodetic baseline to calibrate modern surveying instruments and minimize their error rate.

The purpose of setting up this control base was mainly to verify precision instruments of a few millimeters such as geodetic total stations and laser scanner instruments for educational and research activities. The total station instruments can be checked for (i) zero error ("instrument-reflector constant"), and (ii) its measured length's standard deviation and its compatibility with the specified one by the manufacturer. In addition, reflectorless total stations and laser scanners can be verified against the manufacturer's specifications and tests regarding their behaviour against various materials in order to define correction functions (in relation to material and distance) can be possible. It is emphasized that instruments either of time-of-flight principle or phase difference or using both principles can be tested. The control field was implemented with five specially designed bases made by steel (following ISO 17123-4 specifications). These were embedded in the wall at specified distances in such a way that their heads were on the same horizontal plane (of few mm accuracy). The dedicated design of the bases are designed so that their head carries an integrated 5/8 bolt to be able to attach a tribach in a unique way ("forced centering") to place instruments and accessories (Fig. 2). Figure 2 shows specially designed bases with distances between the bases (baseline reference distances) measured using the three EDM instrument; SOKKIA 530R3, SOKKIA 630R, and Wild DI 10.

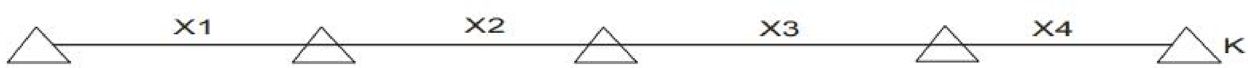

Figure 2: Established Pillar Points at Gidan- kwano campus, FUTMINNA.

The verification procedure of the established baseline transpired by mounting the instrument on the base pillar and record the reading by placing the reflector prism on the other base pillars. For all the five pillars, the reading process took place by taking one station as base station where instrument was placed whereas, the other station acted as forward sight and back sight (EDM Calibration Handbook, 2014).

Considering the station B, the back sight was station A and the forward sight were C, D, and E. For C, the back sight stations were A and B whereas the forward sight is D and E. If taking D as base station then back sight were A, B and C and forward sight was E s (Volker and Tony, 2014). But for the station A and E, the case was different. In the case of station A, there was no back sight, all the four stations acted as forward sight. And for the station E there was no forward sight, the four remaining stations acted as back sight (Volker and Tony, 2014).

Before the process of acquiring the readings started, the temperature was noted. This factor was added or set in the instrument before the reading were acquired (Allan *et al*., 2011) The temperature is measured by using the hand-held thermometer (Zakari and Aliyu, 2014).

Results and Analysis

The process of calibration by the method cited earlier is was done three times. After that the mean of all the readings is was computed to generate the results. The instruments calibrated were SOKKIA 530R3, SOKKIA 630R, and Wild DI 10

in three different rounds on 26th March 2023, 28th March 2023 and 1st April 2023. It was assured that in all three rounds temperature average temperature was same.

The results obtain from the calibration showeds that the reading acquired using these instruments were accurate containing error of approximately 0.6 millimeters. The readings were then analyzed tgo conform to the algorithm of EDM Calibration Handbook, (2014). It is necessary to reject those reading that are were different or in other words are awere outliers of the set of readings acquired in order to avoid errors or discrepancies. Hence, it is essential to refine the readings for the better results (Braun et *al*., 2014).

Considering the distance from A to B, the method used for rejection was that first of all the mean of values are taken and then this mean value is subtracted from the individual distance value which computes „R‟ (EDM calibration Hand Book, 2014). Then after that the highest value is had been detected and eliminated from the dataset. The method is was repeated until the desired results are were obtained.

The formula for computing R is was as followed: R = | X i – X mean |

After analyzing the readings and rejecting the uncertain values the final accepted measurements for all the stations i.e. from A – B, A – C, A – D, A – E, B – C, B – D, B – E, C – D, C – E and D – E are shown in Table 1. The distance for each station is both ways for example if taking into account the distance from A to B then it's also from B-A (similarly for all the stations). The mean of the three sets of horizontal distances, corrected by atmospheric effects, on March 28th, 2023 and repeated on 1/04/2023 were considered for computations and analysis.

Table 1 depicts the field data acquired and its meteorological data on 28/04/2023.

Table 1: Field data acquired on 28/04/2023 at the test facility of FUTMINNA

Date of Observation	EDM Station Order	X	Temp	Pressure	Relative Humidity
28/04/2023	A- B	30.5201	30.5	1012	60%
28/04/2023	B- C	86.5271	30.5	1012	60%
28/04/2023	C- D	158.017	30.5	1012	60%
28/04/2023	D- E	195.025	30.5	1012	60%

Source: Author´s fieldwork, (2023)

Table 2 depicts the final computed distances of the inter pillar points having an estimated RMS as ± 30 µm.

Table 1; Final accepted distance for all stations

S/N	STATION	B	C	D	E
1.	A	30.5201	86.5271	158.017	195.025
2.	B		56.0094	127.503	164.513
3.	C			71.4951	108.508
4.	D				37.0186

Source: Author´s laboratory work, (2023)

The calibration procedure is done only through the electronic distance measurement instruments, therefore it is recommended that the calibration procedures should also be done through the calibrated steel tapes

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Conclusion

The main purpose of this project was to establish an accurately measured geodetic baseline which has been achieved in the form of 5 bay station established in Federal University of Technology, Minna (Gidan Kwano-campus). This facility would be an asset for the university as it will initiate all the surveying approaches required for construction of the fully functional baseline for the calibration of the EDMs.

The study recommends that another set of measurements be carried out using calibrated Invar Steel Wire or Tape for further verification at a future date. In addition, a future plans to include collimators for horizontal and vertical angular control, as well as two fixed points on the floor, with high precision altimetry, should be placed in the same space so that altimeter systems can be controlled

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