Establishment of Calibration Baseline

Olabode Bamidele FATEYE and Kehinde Olusegun ISHOLA

Federal Polytechnic Ado-Ekiti, Nigeria

I. INTRODUCTION

Whenever a new tape is purchased or when a tape has been in use for a long period of time, there is the need to calibrate the tape against a standard usually referred to as baseline. If a tape cuts on the field and it is repaired, the tape would be required to be tested against a baseline as well to know the extent to which it has increased or decrease in nominal length.

Baseline is the starting line or position for the purpose of measurement and it also serves as reference line for conducting surveys. The formation of baseline will aid in the correction and standardization of direct distance measuring instrument such as tapes and chains. The tapes once calibrated on baseline determine its errors.

The establishment of baseline is an important part of the surveying operations which helps in ensuring correct distance measurements in traversing, triangulation and setting out amongst others. According to Zakari and Aliyu (2014), 'The measurement of baseline was in the past century carried out by instruments such as tapes, chains bands before the advent of Electromagnetic Distance Measuring Instrument (EDM)'. Tomlinson et al (2014) observed that to assure that the measuring accuracy as well as operating precision capabilities of an instrument has not significantly deteriorated, a known distance of high accuracy or, preferably, a sequence of distances forming a calibration range or base line is required. Experience shows that a base line consisting of four in-line monuments spaced at specific intervals will meet the needs of users.

The essence of having four in-line monuments in baseline establishment could be to cater for different nominal lengths of tapes in a single baseline. For example, a tape of 30m, 50m and 100m can be calibrated on the same baseline. This means that the four in-line values are 30m, 50m, 100m and 180m length.

Recently there have not been enough steel tapes available for students practical and projects in the survey store of the department whereas many spoiled tapes are there lying in the store without repairs. If these tapes are repaired there would be the need to calibrate them and there is no calibration baseline at the Polytechnic.

This project work establishes baseline for the calibration of tape length 30m, 50m and 100m, all lying along the same line. Distance of each segment of the baseline was measured for 20 times in order to cater for precision of the observations.

II. PROJECT SITE

The project site is situated within the Federal Polytechnic Ado-Ekiti, Ekiti State Nigeria along the road from Administrative block roundabout to the New School of Environmental Studies. They are the points marked red as shown in figure 1. The institution lies between latitude 7˚32'0" N and 7˚37'0" N, and longitude 5˚17'0" E and 5˚20'0" E. The Polytechnic has four Schools and twenty-six academic departments offering National Diploma and Higher National Diploma courses.

Figure 1: Map showing project site

III. LITERATURE REVIEW

The word calibration may mean different thing to different people depending on their field of studies (Jezko, 2014; Beamex, 2019; Savvaidis *et al*, 2004). Calibration is achieved by means of a direct comparison against measurement standards or certified reference materials. A baseline can be defined as a standard measurement set out which serves to monitor and evaluate the performance of a measuring device like tapes and chain which has been in use over a long period of time. Baseline is a set of pillars, ranging from few to more than ten, at distance varying from ten of meters to one kilometre (Samad *et al*, 2016).

A distances set out on the ground with utmost accuracy can be referred to as a baseline. Calibration baselines can be short (up to 30-50 m) and located in a laboratory facility or long (up to several hundred m) and located in the field. They are permanently divided into segments marked by specially constructed pillars. Forced centering systems are used on the pillars in order to eliminate setting-up errors. The stability of the pillars must be monitored to ensure the required calibration accuracy. Both types of baselines can be used for the determination of the EDM errors.

The length of the baselines - to be used as a standard - can be measured by high accuracy EDM instruments or laser interferometers. Laboratory (short) baselines, known also as horizontal comparators, utilize PC-controlled automatic procedures for the calibration of EDM instruments (mainly cyclic errors and additive constant) (Savvaidis *et al*, 2004).

Baseline measurement is an important aspect in the surveying operations such as traversing, triangulation, trilateration, setting out etc. The measurement of baseline was in the past century carried out by instruments such as tapes, chains bands before the advent of Electromagnetic Distance Measuring Instrument (EDM). Distance measurements by electromagnetic means have virtually replaced the method of measuring baseline using the early instruments. Baselines can also be computed from coordinates. For instance main side control points, such as traverse station can be used to establish base line from which setting out can be carried out.

Samad et al (2016) carried out a project work on establishment of geodetic baseline University of the Punjab, Lahore, Pakistan. They established a baseline which was divided into four segments. After the site selection and clearing of the site, the foundation was prepared, smoothened and leveled.

The calibration procedure i.e. acquiring readings by placing the instrument on the base pillars. The verification procedure of the established baseline transpire 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 take place by taking one station as base station where instrument is placed whereas the other station act as forward sight and back sight.

The process of calibration by the method cited earlier is done three times. After that the mean of all the reading is computed to generate the results. The instruments calibrated were SOKKIA 530R3, SOKKIA 630R, and NIKON GTM322 in three different rounds on 26th March 2015, 28th March 2015 and 1st April 2015. It was assured that in all three rounds temperature average temperature was same. The readings once acquired are then analysed. It is necessary to reject those reading that are different or in other words are 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.

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". Then after that the highest value is detected and eliminated from the dataset. The method is repeated until the desired results are obtained. The formula for computing R is as followed: $R = | X_i - X_{mean} |$

After analysing 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 were determined.

Savvaidis et al, (2014) wrote an article on calibrating geodetic instruments. According to them, all survey instrument used for angular measurements, height and distance measurements are subject to errors and need to be calibrated. Theodolites are subject to pointing errors due to focusing, target design, atmospheric conditions etc. Some of the theodolite's errors can be defined using practical methods in the field. In the laboratory, theodolites are calibrated using sets of autocollimators concerning line-of-sight errors, error of vertical collimation, errors of inclination, tuning errors of reading microscopes, errors of compensators and centring devices. Calibration of the angle measuring system can be done either by measuring angles issued by horizontal or vertical collimators in different regions of the theodolite's graduated circular scale or by using a laser interferometer.

Hazelton (2009) explained how to calibrate different instruments. According to him, tapes are much less commonly used for critical measurements these days, and so the need to calibrate tapes is less critical. However, if there is access to a standard measurement line, such as an EDM baseline, it is possible to calibrate a tape. Many EDM baselines include a 100-foot mark for tape calibration. Tapes can also be compared to EDM distances, if the EDM has been calibrated. With all tapes, care must be taken to ensure that the zero point is correctly located with respect to the zero value on the tape.

Jezko (2014) wrote an article on calibration of surveying instruments and tools – means to the quality increase of deformation measurements. The paper describes selected control and calibration procedures of some surveying instruments and tools (digital levels and code bar levelling staffs, total station and electronic tacheometers and reflective systems).

The calibration of horizontal circles of optical and electronic theodolites can be carried out under laboratory conditions, e.g. on an automated device for the calibration of optical polygons EZB-3 in the Slovak Institute of Metrology in Bratislava (SIM). The result of testing the influence of lighting when working with a digital levelling instrument is presented. Furthermore, the procedure and results of the calibration of horizontal circles of surveying instruments on a calibration device are described in the paper.

Halim (2005) defines A calibration base line is a standard length. Several points on a straight line are finely marked on stable permanent piers and the inter-point distances are very accurately measured against the national standard of length. The primary purpose of calibration baseline is to provide precisely known distances on suitable platforms to calibrate tape instruments, which typically measure in the range from 30meters to 100 meters. A precise calibration base line is the cheapest and easiest way of determining and monitoring the performance of tape instrument. By measuring different combinations of lengths of lines on a base line and comparing these values to the adopted values, a user can determine the scale of correction to be applied to all measurements for that instrument-reflector combination. If a regular program of instrument calibration is adopted, users will be able to identify frequency changes, malfunctions or operators errors before unreliable measurements are made, therefore, reducing the need for costly field re-measurements.

IV. METHODOLOGY

The data used in this project work are both primary data and secondary data. The primary data comprises of the distances measured with tapes and total station on the field while the secondary data includes all aspect derived from books, journals, magazines and other internet resources.

The materials used for the project work both field work and office work are Total Station, 100m Steel tape, reflector, Cutlass, Digging rod, Head pan, Shovel, Cement, Sand, Gravel, 12’ Iron rod, Casio programmable calculator.

A Total Station instrument and a reflector were used to set out the baseline. The instrument was set up on a point marked as point 1. The direction was defined by pointing the total station instrument in the predetermined direction. Points were marked along the direction to form the baseline. After that, the following operation was carried out. The height of the total station instrument and reflector’s height were measured with line tape and recorded in the field book. The total station was used in measuring a distance of 30m from the first station (station A) in which a steel tape was also used in determining the actual length, here a 30m point was marked which serves second station (station B).

The instrument was been moved from station A to station B in which the temporary adjustment was also performed. The instrument was also used in measurement of the next station (station C) in which a 50m length was also measured along the align line. The last observation were carried out whereby the instrument was been shifted to station C in which the last measurement was carried out by measuring a distance of 100m to station D which was the last measurement

Figure 2: Setting out Baseline Points

The materials used for demarcation of the set out points are mixture of cement, sand with lot of gravel before adding water. The demarcation pillars casted directly on site at each of the point. Steel reinforcing rod is used to avoid cracking as a result of rapid drying and marking of the centre of the beacon then, the dug hole were wet with water.

Concrete mortar was poured in place in a hole dug in the ground. The hole was dug to a depth of 0.5m (1.5ft) in a square shaped of 0.36mm (1.2ft). The width of the hole for the monument is enlarged about 5cm in radius. Concrete was poured and tampered in the hole until the level is reached. After the concrete level has been reach it was been allow for the concrete to become solid then the numbering of the beacon was done consecutively BSL 001, BSL 002, BSL 003 and BSL004.

Figure 3: Pictures of demarcated points

The length of each baseline station was measured using total station with reflector under identical condition to determine the relative precision of the instrument. The instrument is set up on the first point BSL 001 and the necessary instrument test and adjustment was done. The instrument is centered accurately on the station point, leveled appropriately in order to avoid error/blunders. The reading were taken thereby ensuring the next station where the target were placed i.e.

(BSL 002) by focusing carefully to avoid wrong sighting of target and wrong reading/booking. Then the readings of 10 measurements were booked between station BSL 001 and BSL 002.

However, after A-B measurement had been taken, the instrument was disleveled and further moved to BSL 002 and similar procedure /operation on the station point then back to the previous station and forward to the next station BSL003, the reading 10 times were also taken and booked.

Finally the instrument was moved to BSL 003 and the necessary operation was performed, the total station was been used in observing BSL 004 where the reflector was placed and the reading of 10 measurement were also taken and booked as BSL 001- BSL002, BSL 002- BSL 003 and BSL 003-BSL004 respectively.

The mean, which is the best value of series of measurements can be used in the place of a true value. Therefore in this project work the mean of each set of observation was calculated using the formula below:

$$X = \frac{\sum x_i}{n} \quad \text{......eqn. 1}$$

Where x_i = Mean

n = Numbers of measurement
i = Individual measurement in the series

The mean of each measurement was subsequently used in the least square adjustment. However, the standard error of each of the mean was calculated using the formula.

$$\sigma_m = \frac{\sigma_s}{\sqrt{n}} = \frac{\sqrt{\sum v_i^2}}{n(n-1)} \quad \text{......eqn. 2}$$

Where: σ_m = standard error of mean
σ_s = standard error of observation
v_i = residual
n = number of measurement

V. RESULTS AND DISCUSSION

A total number of 4 point were set out which were numbered BSL001, BSL002, BSL003 and BSL004. The table below shows the total station measurement of each of the segment

Table 1: Distance measurement

S/N	AB (m)	BC (m)	CD (m)
1	29.969	49.884	100.097
2	29.986	49.904	100.102
3	29.958	49.906	100.100
4	29.981	49.906	100.111
5	29.986	49.895	100.118
6	29.957	49.885	100.121
7	29.951	49.891	100.113
8	29.939	49.893	100.114
9	29.931	49.891	100.117
10	29.941	49.879	100.114

Authors' fieldwork (2019)

The result of the calculated mean, and standard error of the mean are shown in the table below.

Table 2: Mean and Standard Error of Mean

ITEM	AB	BC	CD
Mean	29.9599	49.8931	100.1107
Standard Error	0.0063	0.0031	0.0026

Finally, the most probable value or the adjusted value calculated from the least squares adjustment are AB = 29.960m, BC = 49.893m and CD = 100.111m.

During the measurement of the stations when performing the setting out operations of the loops, distance of 30m, 50m and 100m were taken. But after the demarcation of monument of the stations, when the measurement were taken during the measurement of baselines, there is a change in measurement of distances.

In the station BSL001- BSL002 there was a measurement of was an assumed mean measurement of 29.9599m and between station BSL 002- BSL 003, there was also an assumed mean of 49.8931m and between station BSL003 – BSL 004 there was also a measurement of 100.1107m. In the measurement above there is a reduction between BSL 001 –BSL 002 and BSL002 – BSL 003, But between the measurement BSL003-BSL 004M there was an increase in the measurement.

These observable differences may have occurred due to Systematic error, Instrumental error, Atmospheric error of the place or error when adjusting the measurement distances.

VI. CONCLUSION

This project work has successfully established a baseline which can used to calibrate new and old tapes alike. In order words new tapes purchased in the department or any other department of the institution can now be standardized to enhance their performance and accuracy. It is also important to conclude that the applicability of adjustment computation in surveying practice has been demonstrated for the accurate measurement in surveying and engineering works. Even though the work was a tedious one the cost of not establishing such baseline would be more costly.

Based on the aforementioned, I wish to recommend that the baseline established should be put into use by the students of the Surveying and Geoinformatics department, and all other departments of the polytechnic that makes use of measuring tape of any kind in order to maintain standardization in their distance measurements.

The baseline established is for calibrating measuring tapes, therefore I recommend that similar project works should be carried out to establish baseline for calibrating Total Station and leveling staff in the department.

I also want to recommend that the established baseline should be taken proper care of by constantly clearing the grasses surrounding the stations so that the demarcation concrete can last longer.

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