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CHECKING MANUFACTURER'S HEIGHT ACCURACY OF A TOTAL STATION

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ABSTRACT

It is always expected to test the accuracy of surveying instrument as soon as it is purchased or even after being used for considerable time and at regular intervals to check whether it meets the parameters claimed by the manufacturer or not. This paper reports about a test erformed within the boundary of the college of technology in Riyadh to investigate the accuracy of a SOKKIA SET 530R Total Station (TS) survey instrument available in the college and to compare that with what has been claimed by the manufacturer. An optical automatic precise level (Sokkia B21), supposed to have 1.5 mm accuracy for 1 km double-run levelling, was used to work as reference for testing elevations obtained using this total station. A loop traverse of ten points within the fence of the college was established for the test. Reduced levels of nine of the ten points were determined using Sokkia B21 automatic precise level observations with the tenth point used as a Bench Mark (BM) with a given reduced level. Closure error obtained using the level was 0.002m. The same BM was used as a reference point for the total station to obtain levels of the rest nine test points. Results showed that the accuracy of the height accuracy of the total station was 0.005m when compared to levels of the nine points obtained from the level observations. This result agrees well with the accuracy claimed by the manufacturer.

INTRODUCTION

The main objective of surveying is the determination of relative position of points on, above or below the surface of the earth by means of field measurements including linear, angular and elevation measurements. One of the important results of that is to establish three dimensional positions of points to be used as control for construction engineering, ground or photogrammetric mapping, digital elevation model formation and some other purposes. One of such instruments is the Total Station (TS) which is a combination of electronic theodolite for angle observation, an electromagnetic distance measuring instrument for distance measurement and a processing unit to process the observed data and show required information one of which is the three dimensional coordinates of observed stations.

Another important issue in this process is the accuracy of the obtained three dimensional coordinates. For this reason appears the importance of instrument calibration. The calibration concept goes back to the earliest of times when surveyors checked or calibrated their measuring devices against the standard of the day. As an example is the use of the 'standard tape' to 'calibrate' steel tapes. The advent of electronic distance measuring equipment required the establishment and use of baselines to calibrate this type of equipment. Later on when global positioning systems became the measuring tools of the day validation base nets were added to the list of calibration tools (Engler, 2012; Michalcia and Onose, 2014). The calibration and the accuracy verification of surveying instruments, however, is a vital issue for their use in every field of scientific and professional technical work (Reda and Bedada, 2012; Jezko, 2014; Siddiqi, 2015).

a- Surveying instruments such as differential levels, theodolites, total stations, 3D scanners, GPS/GNSS are commonly used to obtain ground point elevation (the third dimension). Nowadays, it is a real necessity to determine height differences between points or the reduced levels of points. Here are some examples of such civil and surveying engineering projects where reduced levels of points are really required.

b- Surveying of levelling networks that are needed for several applications. As an example, McGee, 2014 created a net of leveling for the county of San Francisco that included 670 New and 35 Existing Benchmarks using Leica DNA10 electronic digital level and a pair of 4.05 meter Leica GKNL4 fiberglass bar code rods. The purpose was to study the effect of CCSF that sits between two major faults, the San Andreas & Hayward, on the stability of the city of San Francisco. Future re-surveys of the HPN will be conducted to determine secular and episodic movements in the City.

Marin-Lechado, et al, 2010 monitored the fault- and fold-related activity at the Campo de Dalias, southern boundary of California, USA. In addition using repetitive GPS and high precision levelling that would help to determine future fault behavior with regard to the existence (or not) of a creep component, McGee, 2014.

c- Construction, maintenance and monitoring of huge structures like bridges, dams, very tall buildings, and towers. Accurate measurement of the amount of displacement at predetermined locations over a period of time would always be required (Main Roads, 2017).

d- For planning and estimating project works like roads, bridges, railways, airports, water supply and waste water disposal and pipelines levelling surveying is required (Ceylan, et al, 2005).

e- Determination of vertical crustal movements (Gu, 2005; Henton et al, 2006; Qin et al, 2018).

f- Flood control and navigation surveys. Paringet, et al, 2014 used airborne LIDAR fine scale topographic data to monitoring and managing riverine (fluvial) flooding for a river that recently experienced severe flooding event in the Philippines.

Among the various surveying instruments used today in Technical Colleges and Surveying Engineering institutions is the Sokkia SET 530R total station, mainly used by students for training required for some undergraduate courses and final year graduation projects. This has been selected to be tested as far as height accuracy is concerned.

In this project the following instruments will be used in the test.

- A Differential Level, an optical or digital instrument used to determine difference in level between ground points. Starting from a bench mark reduced levels of observed points can be determined. Reduced levels obtained by a precise level will be used as reference to evaluate the levels of the same points as obtained by the total station whose accuracy is under test.
- A Total Station is an electronic/optical instrument used for different surveying applications. It is an electronic transit theodolite integrated with electronic distance measurement (EDM) to measure both vertical and horizontal angles and the slope distance from the instrument to a particular point on which an optical reflector is fixed, and an on-board computer to collect and process data and perform survey calculations.

One of the information obtained by a total station is reduced levels of points, whose accuracy will be tested in this research.

The objective of this paper is to analyze the results of levelling field work carried out using a precise digital level and a total station to compare the height obtained by total station to that obtained by digital level to determine the total station height accuracy and to compare with that claimed by the manufacturer as ±5mm.

LITERATURE REVIEW

Many researchers studied accuracy of survey instruments: Total station, Level, and theodolite. Some results of research works obtained in testing total station accuracy are outlined below.

The purpose of the study carried out by Ceylan et al, 2005 was to analyze the trigonometric levelling using total station, which is capable of high accuracy observing vertical angles and distances, geometric levelling using digital level and GPS/Levelling using GPS observations. To fulfill this aim, a levelling line with 11 points was established in Alaeddin Keykubat Campus area of Selçuk University. During the study done on this levelling line, three separate geometric levelling with different three surveying instruments (Wild N3 precise level, invar rods, Sokkia B2 automatic level and wooden rods, Sokkia SDL 30M digital level and bar coded aluminum rods), trigonometric levelling by using two different instruments (Wild T2 theodolite for vertical angle measurements and Topcon GTS 701 electronic total station for distance measurements, only Topcon GTS 701 electronic total station for vertical angle and distance measurements) and GPS/levelling (with Leica 9500 receiver) were used. The height differences of precise levelling were assumed as true values, and these differences were then compared with these from other techniques and mean square errors were computed using these measurement differences. Consequently, it was seen that the results from digital level showed the best approach to those from precise geometric levelling.

Jana, et al, 2009 tested accuracy of Leica 1201 total stations, Topcon GPT-7001 and Topcon GPT-8203M. The results of the experiment showed the differences between the accuracy of distance measurements on reflecting prisms and on colored targets with different reflectance. The target reflectance did not significantly influence the accuracy, but the fact, that the distance on dark targets were not measured at all by some apparatus. The increase of the number of individual distance measurement did not lead to the increase of measured distance accuracy, on the contrary, the dispersion of measured values increased.

The Bachelor Thesis on investigation of the accuracy and limitations of automatic target recognition in total stations by Weyman-Jones, A (2010) brings up the issue of obstructions in the line of sight between the TS and the prism target. The term Automatic Target Recognition (ATR) is the term that the manufacturer Leica uses and is the same function that is called auto lock in that thesis , which is the term that the manufacturer Trimble uses. There have been no evaluation result of TS accuracy in this thesis. It is merely example of other issue that could be of interest on the subject of TS measurements

Erikson H.M (2014) investigated measurements made by three TSs (Leica TCRP1203+, Trimble S6 and Topcon GTS-900A) through different type of obstructions such as construction site, fence shade cloth, vegetation simulations, partly covered prisms as well as wet and dusty telescopic lenses. The conclusion was that when the measurements were performed with the test obstructions placed at different distances from the TS in the line of sight, the obstruction made of vegetation caused large randomized errors. When the obstructions were placed in close proximity to the TS there were more sever effects on the precision than if the obstructions were placed further away, by all the different obstructions tested. Especially the obstruction made of glass caused very large angular errors when it was placed close to the TS.

METHODOLOGY

Tests will be carried out on a closed traverse which originates from a station and returns to the same station completing a circuit. One point will be taken as the reference or control with known planimetric position and reduced level. Sides of the traverse will be measured using Total Station, traverse angles will be observed using theodolite and levels will be measured using an optical level while coordinates of all points will be recorded by the total station on observing reflector being moved from one station to the other. Test site, tested instruments and detailed steps of observations will be explained in the following sections.

Test Site

The traverse is located in the north - east of the college of technology in Riyadh, capital of Kingdom of Saudi Arabia (KSA) (figure 1). The traverse is composed of 10 points.

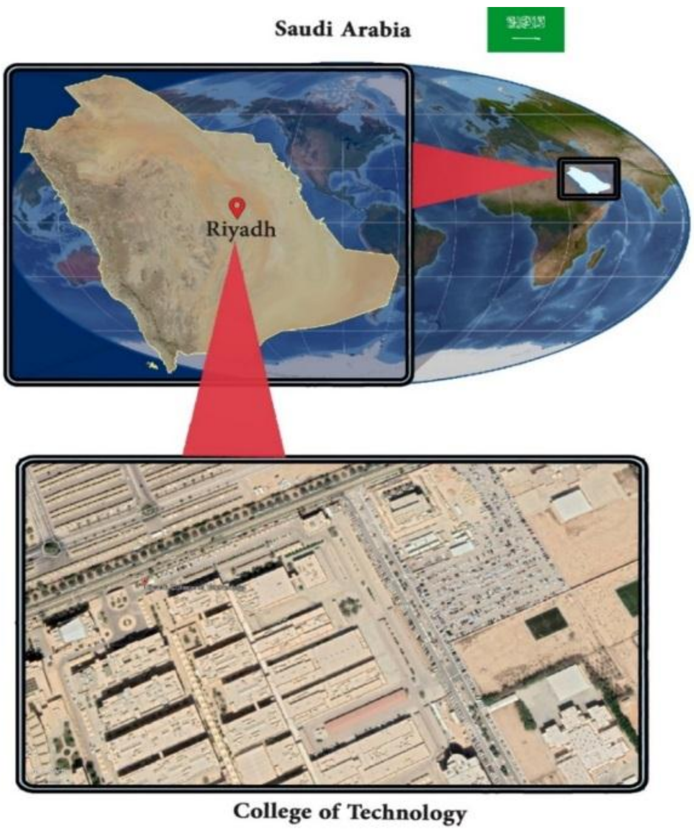

Fig. 1: Riyadh KSA Capital and College of Technology.

Test Instruments

Level: SOKKIA B21 (Figure 2), used to collect reference data.

Fig. 2: Sokkia Precise Automatic Optical Level.

The B series Sokkia Auto levels incorporate a precise and reliable compensator. The manufacturer states the following description of the level

- Leveling Accuracy: B20 – ±0.7mm;
- Telescope Magnification: B20 – 32x;
- Minimum focus distance: 0.2m from end of telescope, 0.3m from instrument center

- Precise, Reliable Automatic Compensator
- Quick collimation with two horizontal motion knobs
- Superior telescope with two-speed focus knobs

Total Station: SOKKIA SET 530 R. (figure 3) to be tested

Fig. 3: Sokkia Total Station.

SET530R3 Specifications as provided by manufacturer

Telescope fully transmitting, coaxial sighting and distance measuring optics.

Magnification 30x; Resolving power 2.5″; Field of view 1°30″ (26m/1,000m)

Minimum focus 1.3m (4.3ft)

Angle measurement Photoelectrical absolute rotary encoder scanning. Both circles adopt diametrical detection.

Display resolutions H&V 1″ / 5″, 0.2mgon/1mgon, 0.005 mil, selectable

Accuracy (ISO12857-2 1997) H&V SET530R3 – 5″ (1.5mgon)

Measurement mode H: Clockwise / Counterclockwise, 0 set, Hold, angle input, repetition, available V: Zenith 0°, Horizontal 0° ±, slope in %, selectable

Automatic dual-axis-compensator Range: ±3′ (±55mgon), “out-of-range” warning display provided

Distance measurement Modulated laser, Laser diode, Coaxial EDM transmitting and receiving optics (IEC Class 3R, FDA Class 3R laser)

Maximum measuring range A: Average conditions: slight haze, visibility about 20km (12miles), sunny periods, weak scintillation. B: Good conditions: no haze, visibility about 40km (25miles).

Accuracy

- Reflector-less below 200m: ±(3 + 2ppm x D)mm; Over 200 to 350m: ±(5 + 10ppm x D) mm
- § With reflective sheet ±(3+ 2ppm x D)mm
- § With AP prism ±(2 + 2ppm x D)mm
- Internal memory About 10,000 points
- Memory card unit*2 Optional. The 8MB CF card stores approximately 72,000-point data
- Scale factor setting 0.5 to 2.0
- Interface Asynchronous serial, RS-232C compatible, baud rate: 1,200 to 38,400 bps
- Printer output Centronics compatible (w/ optional DOC46 printer cable).

Steps to execute the project

- Selecting the location of traverse points as shown in figure (4).
- Test points observations using Level.
- Test points observations using Total Station

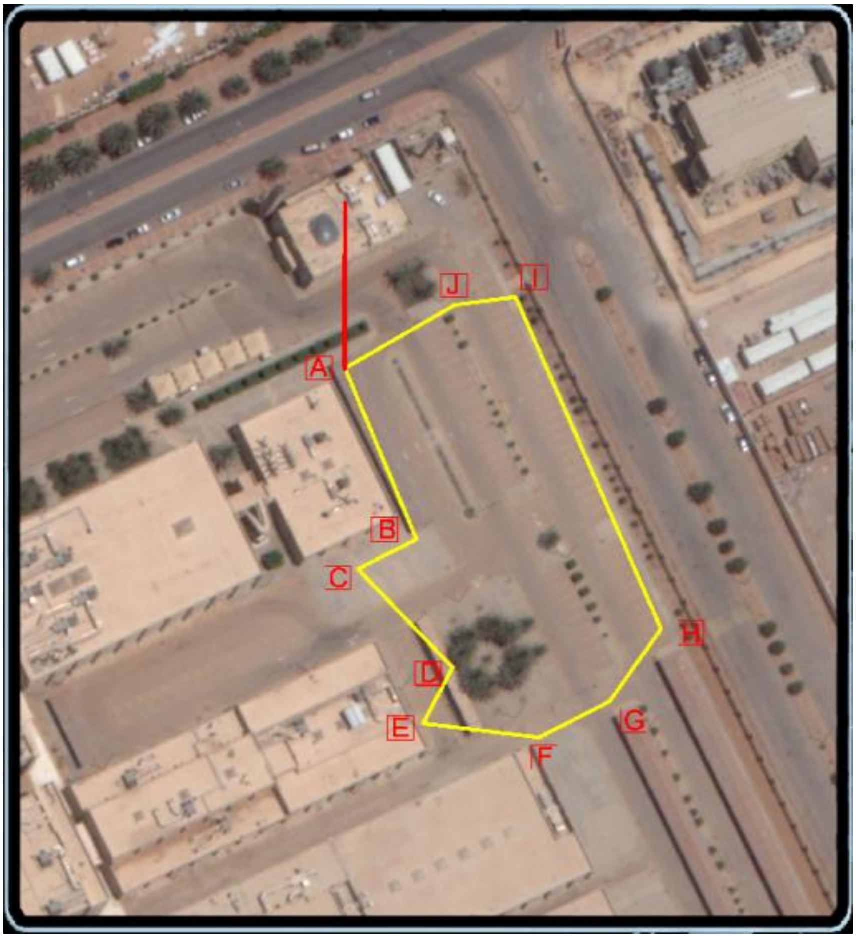

Fig. 4: Traverse Control and Test Points.

For each instrument measurements started from point A and go through the rest of the points and back to point A again.

4- RESULTS AND ANALYSIS

Levelling results of observation using SOKKIA B21 level are given in Table 1.

Table 1: Levelling Table of Level observations.

Test Point	Back Reading (m)	Fore Reading (m)	Rise (+) or Fall(-) (m)	Reduced Level (m)	Remarks
A	1.508			600.000	Assumed BM
B	1.525	1.500	0.008	600.008	
C	1.329	1.520	0.005	600.013	
D	1.338	1.330	-0.001	600.012	
E	1.281	1.352	-0.014	599.998.	
F	1.498	1.395	-0.114	599.884	
G	1.373	1.550	-0.052	599.832	
H	1.615	1.192	0.181	600.013	
I	1.328	1.664	-0.049	599.964	
J	1.310	1.324	0.004	599.968	
A		1.276	0.034	600.002	
Σ	14.105	14.013	0.002		
Check	14.105 14.013 = 0.002		0.002	0.002	OK

Level Closure error = Observed Level of BM – Given Level of BM = 0.002m

Levels of test points obtained using differential precise level and total station are both given in Table 2. The table also includes statistical results including residuals at all test points, population standard error and standard error of the mean for total station results as compared to the precise level.

Table 2: Traverse control and test points reduced levels using Level and Total Station.

Staff Point	RL from Level x', (m)	RL from TS x”, (m)	Residual, x' – x”, (m)	Residual^2 (x’ – x”)^2	Remark
A	600.000	600.000	0.000	0.000000	BM
B	600.008	600.002	-0.006	0.000036	
C	600.013	600.006	-0.007	0.000049	
D	600.012	600.000	-0.012	0.000144	
E	599.998	599.995	-0.003	0.000009	
F	599.884	599.879	-0.005	0.000025	
G	599.832	599.828	-0.004	0.000016	
H	600.013	600.011	-0.002	0.000004	
I	599.964	599.959	-0.005	0.000025	
J	599.968	599.964	-0.004	0.000016	
A	600.002	600.004	0.002	0.000004	Back to BM
Σ				0.000328	

Standard error = $\sigma = \frac{\pm\sqrt{\Sigma(x'-x")2\,/(n-1)}}{n} \quad = \frac{\pm\sqrt{(0.0003)/(8)}}{10}$

$= \pm 0.006$m

Standard error of the mean = $\frac{\pm\sqrt{\Sigma(x'-x")2\,/n(n-1)}}{n-1} \quad \frac{\pm\sqrt{(0.0003)/(9)(8)}}{9}$

$= \pm 0.002$m

It is clear from tables 1 and 2 that results obtained using level and total station are 0.002m and 0.006m, respectively. This indicates that both are within the accuracy claimed by the manufacturer.

5- CONCLUSIONS

In concluding, the Project studied height accuracy of a Total station based on data given by a precise automatic level for a traverse of 10 points, one used as control. The closing error of the level was 2mm.

All observations were carried out afternoon, when the weather was fair with field temperature not exceeding 20^{o} C.

Results show that the total station can give height accuracy of 6mm. This is very near to what have been claimed by the manufacturer. This means this tested total station can be further used without need to constants and error correction. However, calibration should be repeated at maximum within 6 months.

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