wjert, 2019, Vol. 5, Issue 6, 362-371. *Original Article* ISSN 2454-695X

World Journal of Engineering Research and Technology
WJERT
www.wjert.org
SJIF Impact Factor: 5.924

COMPARISON OF AUTOMATIC LEVEL AND THEODOLITE PERFORMANCE IN HEIGHT DIFFERENCES MEASUREMENT

Suhardi*

Department of Agriculture Engineering, Jember University, Jember, 68121, Indonesia.

Article Received on 06/10/2019 **Article Revised on 27/10/2019** **Article Accepted on 17/11/2019**

***Corresponding Author**
Suhardi
Department of Agriculture Engineering, Jember University, Jember, 68121, Indonesia.

ABSTRACT

Two leveling equipment, an automatic level sokkia B20, a modern theodolite sokkia DT 510, are equipment used to measure the difference in height of a land surface. The features and difficulty of operating on each of these devices vary. The operation and features at the automatic level are simpler than a modern theodolite. Based on these differences, it is expected that the accuracy of the measurement of the height difference produced is also different. This study aims to determine the level of accuracy of automatic level and modern theodolite equipment in measuring height differences. Based on measurement data and analysis results show that automatic level equipment has a high accuracy measurement of height on third order leveling standards was 11 mm. While modern theodolite equipment has a higher measurement accuracy as 2 mm.

KEYWORDS: Automatic level, modern theodolite, accuracy, height differences.

INTRODUCTION

The purpose of this study was to determine the accuracy of automatic level and modern theodolite equipment in measuring height differences. While the expected research benefits are the availability of good automatic level and modern theodolite equipment and produce measurement data with high accuracy.

Height difference measurement is the basic science of geomatics techniques in calculating height differences between two or more measurement points. Height difference measurement results are used to determine the elevation of each point. The results of this height difference measurement can be used for various purposes including channel planning, road planning, the opening of new agricultural land, landfill planning and excavation planning, airfield planning, and others (El-Ashmawy, 2014). In general, the equipment that is often used for height difference measurements is an automatic level and a modern theodolite.

The Automatic level equipment feature is used to set the automatic optical level in a flat position using three regulating screws. Flat position automatic optical level can be determined based on the position of circular vial being in the inner circle at the circular level (Adebayo, Emenari and Uwaezuoke, 2014). The automatic level was set in a flat position to improve the accuracy of height difference measurements. Very accurate automatic levels are used for measurement of height differences (Rinaldy and Anwari, 2013) (Saghravani and Mustapha, 2009). While the modern theodolite composed of complex features and wider use. the modern theodolite equipment used to measure the height difference and polygon. Besides, this modern theodolite equipment can be used to measure height differences in mountainous areas with high contour, because of the theodolite equipment composed of a telescope that can be moved vertically up and down. This telescope is equipped with an eyepiece and an objective lens which is equipped with a focusing ring so that it can see objects clearly (Avram *et al.*, 2016). Knowledge of the reliability and accuracy of levelling equipment is necessary so that the results of the measurement of the height differences produced are suitable with the needs of the project (Beshr and Abo Elnaga, 2011). Moreover, the long service life of the equipment will reduce the reliability and accuracy of the equipment in the measurement of height differences. Therefore, automatic level and modern theodolite must always be evaluated to ensure their level of accuracy in measuring height differences. Evaluation of the performance of automatic level equipment and modern theodolite becomes a very important thing to ensure that the equipment is still in good condition. If the evaluation results show that the equipment's performance is good, then the equipment can be used more without giving an error correction value but needs to be recalibrated for a maximum of 6 months (Elhassan, 2019).

The arm of this study was to determine the accuracy of automatic level and modern theodolite equipment in measuring height differences. While the expected research benefits are the availability of good automatic level and modern theodolite equipment and produce measurement data with high accuracy.

MATERIALS AND METHODS

Research Site

This research was conducted in the Department of Agriculture Engineering, Agricultural Technology Faculty, Jember University, Indonesia. There were 10 polygon points measurement of the height difference as shown in Figure 1.

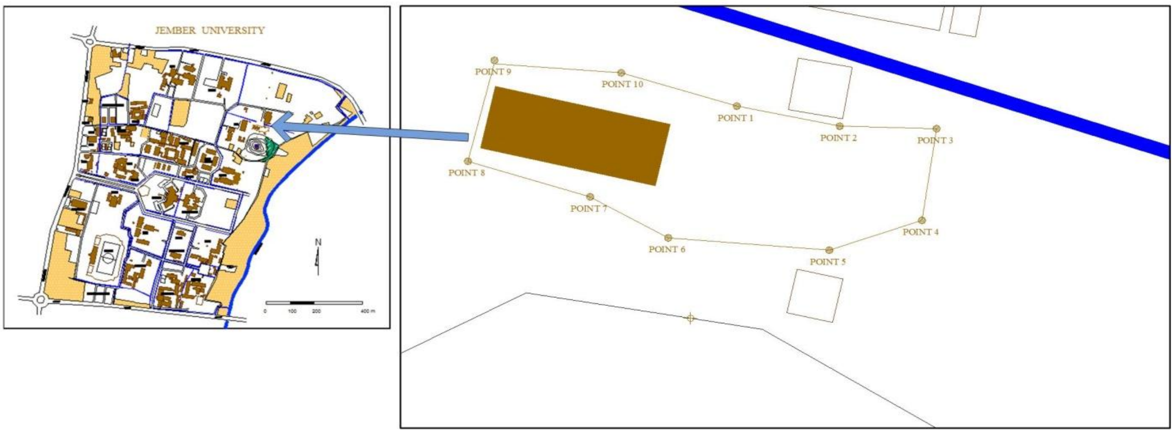

Fig. 1: Department of Agriculture Engineering, Jember University.

Automatic Level and Theodolite

The equipment used in this study includes one automatic level unit (Sokkia B20), a modern theodolite unit (Sokkia DT 510), meter rollers and hammers. Automatic level units and theodolite units are equipped with a tripod and levelling staff. The Automatic level consists of several features including base plate, horizontal fine motion screw, circular level, pentaprism, focusing knobs, peep sight, and telescope. Meanwhile, a modern unit of theodolite is equipped with very complex features such as targeting sight, objective lens, operating keys, circular vial, tripod base plate, handle, nurse mark and vertical plate, horizontal fine screw, horizontal clamp and tubular vial such as shown in Figure 2 and Figure 3. While the material used was pins and stationery.

Fig. 2: Diagram of automatic level.

Fig. 3: Diagram of modern theodolite.

Research Stages

This research consists of several stages: determining the point, measuring the difference in height at polygon point, and analyzing the data. The stages of the research are described as follows (Fig. 4)

a. The automatic level and modern theodolite place between point 1 and point 2, and measurement of the back reading point 1 (R1) and fore reading point 2 were done (V2).

b. Move the automatic level and modern theodolite to the position between point 2 and point 3 and follow the procedure a

c. Perform procedure b for the measurement at point 3 and point 4 until returning to point 1 (Elhassan, 2019).

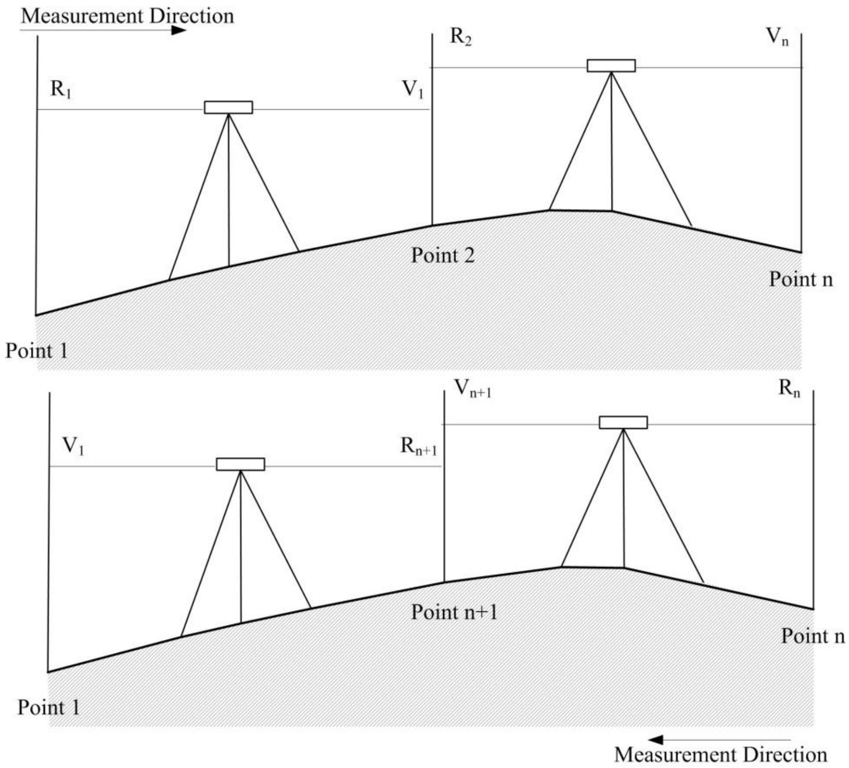

Fig. 4: Diagram Height difference measurement.

Polygon height difference measurements are used to determine the elevation error level of each measurement point. Height difference measurement starts from point 1 moves to the next point in polygons and finishes at point 1 again. Calculation of the height difference (H) between point 1 and point 2, point 2 and point n, and so on is calculated by the following equation (Frick, 1984)

$H = Ri - Vi$.. (1)

Where H = Height difference (m)

Ri = The back reading of levelling staff

Vi = The fore reading of levelling staff

The calculation of the temporary elevation at each point can be written with the following equation

$Rl = H + datum$ .... (2)

Dimana Rl = Reduced level (m)

H = Height difference ((m)

Datum = assumed of BM

Measurement of elevation between two points using theodolite equipment is very possible using the theory and techniques of the stadia tacheometry (Elhassan and Ali, 2011). In the stadia tacheometry technique, the theodolite line of sight towards levelling staff is kept horizontal or tilted inclined with the conditions on the ground as shown in Figure 5 and Figur 6 (Ibraheem and Najeeb, 2016).

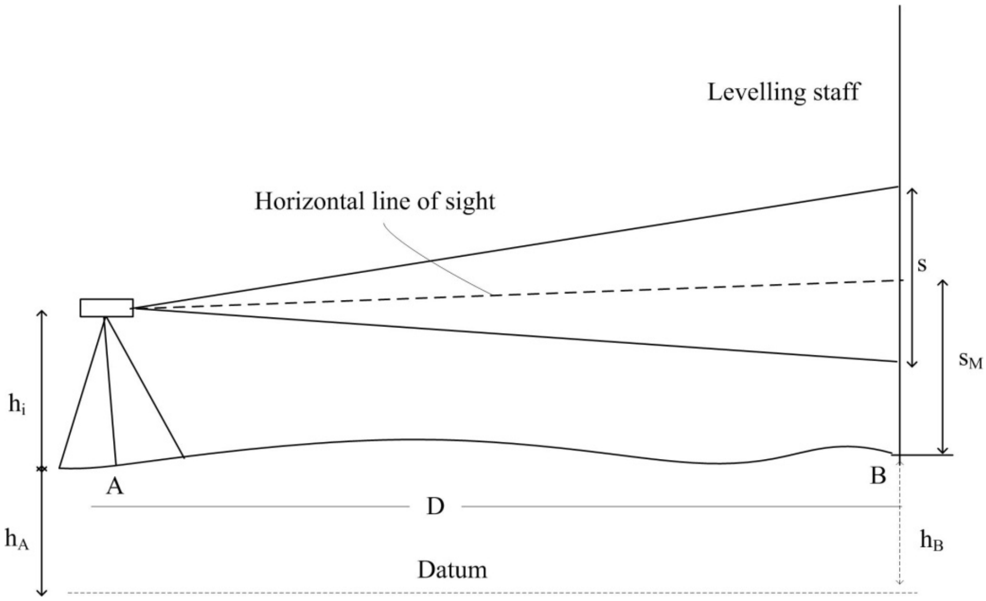

Fig. 5: Horizontal line.

The distance between points A and B can be calculated using the equation:

$D = kS + c$ .... (3)

Where,

K and *c* are the multiplying and additiveconstants of the tachometer, k = 100, c = 0

S = the staff intercept, = *ST – SB*,

ST – SB are the top hair and bottom hair readings,

D = 100 S...(4)

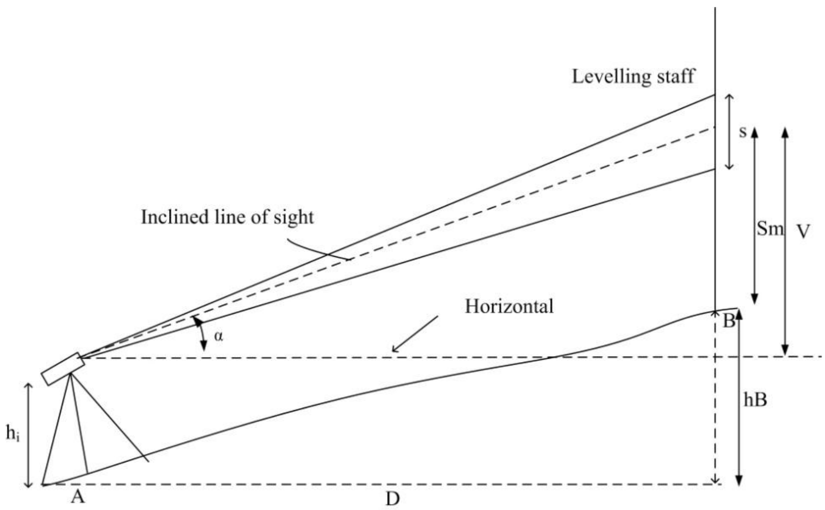

Fig. 6: Inclined distance.

Calculation of horizontal distance (D) and the difference in height (H) between 2 points A and B with a vertical angle α can be calculated use equation 5 and equation 6:

$D = k\ S \cos 2\alpha$ ....(5)

$H = k\ S \cos\alpha \sin\alpha$ ....(6)

Meanwhile, the calculation of the elevation of point B uses the equation 7:

hB= $hA + hi + V - Sm$ .... (7)

Where,

hB = Reduced level of point B, hi = high instrument, hA= datum of point A, Sm= middle stadia, V= vertical distances

The accuracy of height difference measurements using automatic level and theodolite equipment can be calculated with equation 8 to equation 10 below (Abanmy, Ali and Alsalman, 2006)*:*

1. Third order levelling standards

$e = \pm 25\sqrt{K}$ mm ....(8)

2. Second order levelling standards

$e = \pm 12\sqrt{K}$ mm ....(9)

3. First order class 1 levelling standards

$e = \pm 4\sqrt{K}$ mm ....(10)

Where,

K= the lenght of the polygon in km, dan e = accuracy of high difference in mm.

A. RESULTS AND DISCUSSION

Measurement of height differences was carried out at 10 observation points using automatic level Sokkia B20 equipment and modern theodolite Sokkia DT510 using the horizontal line technique. Horizontal line technique on modern theodolite equipment is done by adjusting the vertical angle at the level position (90^o). Calculation results and height differences measurement data are given in Table 1 and Table 2.

Table 1: Levelling observations using Automatic Level B20.

Point	Back reading (m)	Fore reading (m)	Height from Ground Surface (m)	Distance between points (m)	Reduced level (m)	Remarks
1	0.945				200	Assumed BM
2	1.146	1.302	-0.357	20.00	199.643	
3	1.035	1.212	-0.066	20.00	199.577	
4	1.265	1.138	-0.103	20.00	199.474	
5	1.240	1.183	0.082	20.00	199.556	
6	1.240	0.682	0.558	26.20	200.114	
7	1.359	1.153	0.087	19.60	200.201	
8	1.470	1.448	-0.089	20.00	200.112	
9	1.427	1.509	-0.039	20.00	200.073	
10	1.343	1.414	0.013	20.00	200.086	
1		1.418	-0.075	20.00	200.011	Back to BM
∑	12.470	12.459	0.011	205.80		
Check	0.011		0.011		0.011	

The accuracy of automatic levels range from third order levelling standards:

$$e = \pm 25\sqrt{K}$$

$$= \pm 25\sqrt{0.2058} = 11.341 \text{ mm}$$

Table 1 shows that the accuracy of height differences measurements using automatic level equipment was 11 mm. Meanwhile, the calculation of accuracy in third order leveling standards is 11.341mm. Thus it can be stated that the accuracy of the height difference measurement using the automatic level Sokkia B20 was included in the third order leveling standards.

Tabel 2: Levelling observations using modern theodolite DT510.

Point	Back reading (m)	Fore reading (m)	Height from Ground Surface (m)	Distance between points (m)	Reduced level (m)	Remarks
1	1.060				200	Assumed BM
2	1.258	1.414	-0.354	20.00	199.646	
3	1.169	1.329	-0.071	20.00	199.575	
4	1.269	1.270	-0.101	20.00	199.474	
5	1.281	1.200	0.069	20.00	199.543	
6	1.320	0.724	0.557	26.20	200.100	
7	1.285	1.232	0.088	19.60	200.188	
8	1.604	1.362	-0.077	20.00	200.111	
9	1.556	1.648	-0.044	20.00	200.067	
10	1.522	1.548	0.008	20.00	200.075	
1		1.599	-0.077	20.00	199.998	Back to BM
∑	13.324	13.326	-0.002	205.80		
Check	-0.002		-0.002		-0.002	

The accuracy of modern theodolite range from second order levelling standards :

$e = \pm 12\sqrt{K}$

$= \pm 12\sqrt{0.2058}$ = 5.444 mm

Table 2 shows that the accuracy of height differences measurements using modern theodolite sokkia DT510 equipment was 2 mm. Meanwhile, the calculation of accuracy on second order levelling standards was 5.444 mm. Thus it can be stated that the accuracy of the height difference measurements using modern theodolite sokkia DT510 was included in the second order levelling standards.

CONCLUSIONS

Measurement of height differences with polygon length of 0.2058 km using automatic level B20 was accurate at 11mm. Meanwhile, the accuracy of height difference measurements using modern theodolite was better at 2 mm.

REFERENCES

1. Abanmy, F. A., Ali, A. E. and Alsalman, A. S. (2006) ‘Optical, Laser and Digital Levelling: A Comparison of Accuracy in Height Measurement’, *Sudan Engineering Society JOURNAL*, 53(48): 1–13.
2. Adebayo, A., Emenari, U. S. and Uwaezuoke, I. C. (2014) ‘Comparison of Height Differences Obtained from Automatic , Digital and Tilting Level Instruments’, *Journal of Environmental Issues and Agriculture in Developing Countries*, 6(1): 85–92.
3. Avram, D. *et al.* (2016) ‘Surveying Theodolite Between Past and Future’, *Journal of Young Scientist*, IV, pp. 129–134.
4. Beshr, A. A. A. and Abo Elnaga, I. M. (2011) ‘Investigating The Accuracy of Digital Levels and Reflectorless Total Stations for Purposes of Geodetic Engineering’, *Alexandria Engineering Journal*. Faculty of Engineering, Alexandria University, 50(4): pp. 399–405. doi: 10.1016/j.aej.2011.12.004.
5. El-Ashmawy, K. L. A. (2014) ‘Accuracy, Time Cost and Terrain Independence Comparisons of Levelling Techniques’, *Geodesy and Cartography*, 40(3): 133–141. doi: 10.3846/20296991.2014.962727.
6. Elhassan, I. M. (2019) ‘Checking Manufacturer’s Height Accuracy of A Total’, *World Journal of Engineering Research and Technology*, 5(3): 42–53.
7. Elhassan, I. M. and Ali, A. S. (2011) ‘Comparative Study of Accuracy in Distance

Measurement Using: Optical and Digital Levels’, *Journal of King Saud University - Engineering Sciences*. King Saud University, 23(1): 15–19. doi: 10.1016/j.jksues.2010.10.001.

8. Frick, H. (1984) *Science and Equipment Measurement Soil*. Yogyakarta: Kanisius.
9. Ibraheem, A. T. and Najeeb, Z. A. (2016) ‘The Utilization of Stadia Measurements For Different The Utilization Of Stadia Measurements For Different’, *International Journal of Technical Research and Applications*, 3(6): 37–44.
10. Rinaldy and Anwari, C. (2013) ‘Comparing High Difference Measurement Results from GPS and Instrument Leveling Survey’, *Reka Geomatika*, 1(2): 51–62.
11. Saghravani, S. R. and Mustapha, S. bin (2009) ‘Accuracy Comparison of RTK-GPS and Automatic Level for Height Determination in Land Surveying’, *MASAUM Journal Of Reviews and Surveys*, 1(1): 10–13.