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ACCURACY AND PRECISION OF DETERMINATION HORIZONTAL DISTANCES IN STAKEOUT MEASUREMENT USING THEODOLITE

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Abstract

Stake-Out is a processes of transferring construction design to the real world so that Stake Out is highly imperative in a construction job. Stake-Out jobs in the middle and lower levels of construction industry are still using theodolite accompanying with calculator rather than using high-end instruments. The results of the study show that theodolite has lower accuracy compared to Total Station and other high-end instruments, such as GPS Geodetic and Laser Scanner. This research is aimed to determine the accuracy and precision of Theodolite in determining the horizontal distance of Stake Out measurement which staff reading is simulated using android App (Stake Out Guide). The results of experiment showed that the accuracy of Theodolite is 0.025 m meanwhile the precision is 0.12%.

Keyword: Stake Out, Accuracy, Precision, Theodolite.

PENDAHULUAN

One of a highly imperative jobs in engineering surveys is staking out points of geometric design on the earth surface. In reaching the accuracy of stakeout measurement, the deviation standard has to be less than the expected deviation standard (Hendriatiningsih, 2008). Stake-out can be defined as processes of transferring a construction design in the real world by placing pegs on the terrain those have been determined previously in the design (Buchmann, V, 2008). In preparation process choice to use a precise specific instrument to provide the expected results when conduct stake out often becoming a dilemma, because there are available wide arrange of different chemometric models, each of those giving different accuracy, efficiency and opportunity (Tuno et al.). Considering how important stake-out is in the construction industry, so that the stake-out measurement needs instruments with high accuracy and precision. Instruments those frequently used in professional stake out measurement are Total Station and or GPS Geodetic, but in the level small and medium construction enterprises mostly are still using low-cost instruments such as theodolite and level and roll meter. The previous study in theodolite and Total Station comparison shows the accuracy of theodolite distance measurement is 0.3 – 0.2 m, meanwhile Total Station has accuracy 1-10mm+1-5ppm (Sanjeev Gill and Aswin Aryan, 2016).

Precision is dealing with the consistency of an observation group and evaluated based on size differences, and Accuracy is the closeness of the number of observations to the true value (Ghilani, 2007), a further illustration of precision and accuracy are depicted in Figure 1.

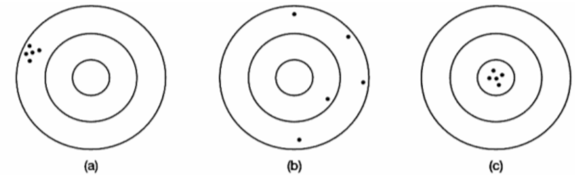


Figure 1. Example of Precision and Accuracy (a) results are precise but have low accuracy (b) results are not precise and accurate, (c) results are precise and accurate. (Ghilani, 2007)

The objective of this research is the determination of precision and accuracy of the calculation horizontal distances based on staff reading in stakeout measurement using theodolite so that the solution can be found to enhance the accuracy of the measurement. In this research, the accuracy and precision are determined uniquely based on instrument and human error is not taken into account because the staff reading is the result of simulation using Stake Out Guide app.

RESEARCH METHOD

This research is conducted by stakeout measurement simulation using the Stake Out Guide app which is available at Google Play. It can be installed in an android smartphone through the following link https://play.google.com/store/apps/details?id=totok.sulistyo.s0. The simulations are conducted by determining coordinates of stakeout locations (fore-sight), coordinates of reference points (back-sight) and location of theodolite. The further step is a calculation of the azimuth and the position of stakeout points theoretically those are accomplished using the Stake Out Guide App.

In the azimuth computation the formula 1 is employed:

$\alpha = arc\ tan\frac{x_2-x_1}{y_2-y_1}$ ……………………………..(1)

Where α is azimuth

Meanwhile in the theoretical horizontal distances calculation the formula 2 is used:

$c = \sqrt{(x_2-x_1)^2+(y_2-y_1)^2}$ ……………..(2)

Where

x_1, y_1 is the coordinate of instrument location, and

x_2, y_2 is the coordinate of stake-out point location.

After getting the horizontal distances of instrument location to stake out point, further step is conducting the simulation of staff reading in the distance close to theoretical distance resulted from calculation, staff readings are conducted many times in different positions, move backward and forward as the instruction of the application till it gets the result which is closest to the theoretical distance. The experiment of measurement simulation is conducted 40 times with random staff reading and vertical angle is incremented by 0°30' or 0.5°.

Then the horizontal distances based on reading staff are calculated using formula 3.

$hd = 100\, S. cos^2\theta$ …………………..…(3)

Where

$hd\ is\ horizontal\ distance$

S = upper crosshair – lower crosshair ..(4)

And

$\theta = 90^o - Vertical\ Angle$ …………..(5)

The range of precision is determined statistically using the deviation standard of measurement result which is calculated uses formula 6 (Li, Xiaolu et al., 2018).

$$E_{pre} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} (R_i - \underline{R})^2} \dots\dots\dots\dots\dots (6)$$

The accuracy analysis is conducted by the comparison of horizontal distance resulted from measurement and horizontal distance resulted from theoretical computation as true value (standard), meanwhile precision analysis is determined by similarity or sameness from the group of data from a couple of measurements. Analysis is conducted merely on horizontal distances, so that in the scatter graphics presentation the point of measurement will be concentrated along the x-axis. The range of accuracy is the level of fitness a couple of measurement to the true value (Li, Xiaolu, et al., 2018), it can be calculated use formula 7.

$$E_{acu} = \frac{1}{N}\sum_{i=1}^{N} (R_i - R_{true}) \dots\dots (7)$$

RESULT AND DISCUSSION

The smallest unit in the staff reading through the telescope of theodolite is 1 mm or in meter, it can be read until the third digit in decimal number. It is impossible to read smaller than 1 mm (see figure 1). The Data entry in the Stake Out Guide app is adjusted to the staff readability in the telescope of theodolite.

The results of calculation and measurement

The simulation of measurement of stake-out based on the following data:

a. the coordinate of instrument (O) x = 20.000 , y = 24.000
b. the coordinate of back-sight (A) x = 10.500, y = 24.000
c. the coordinate of *Stake Out* point (B) x = 28.5000, y = 0.000

Based on the above data, horizontal distance can be calculated theoretically use formula 2, the result of horizontal distance (hd) between O and B calculation is 25.461 m. Meanwhile, the AOB angle is angle two lines of OA and OB. The azimuth of Both line OA and OB are calculated using formula 1. The azimuth of O to A is 270º 0'0" and the azimuth of O to B is 160º 29'51" And AOB angle is resulted from the summation of 360º- 270º 0'0" + 160º 29'51", that is equal to 250º29'30", so the AOB angle is 250º29'30" (see figure 2).

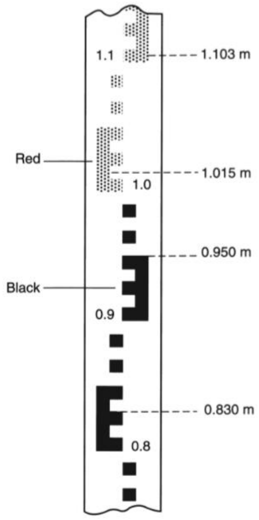


Figure 1. Staff (Schofield et al., 2007)

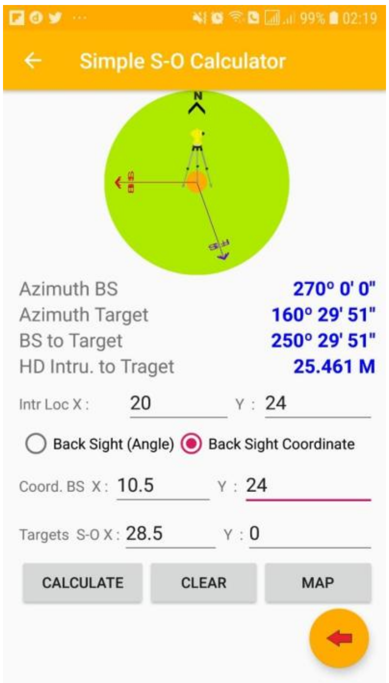
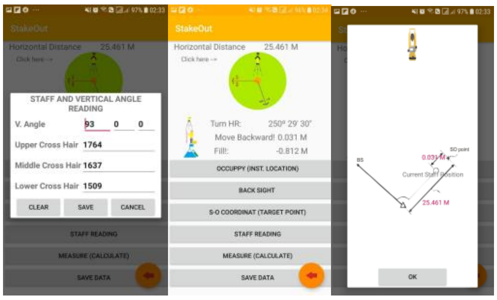


Figure 2. Result of horizontal distance and azimuth in stake-out measurement

The results of staff reading simulation using Stake Out Guide app with vertical angle start at 90º 0' 0", and staff reading which is generate the closest horizontal distance to the O – B distance (25.461), is chosen (see figure 3). In the next simulation vertical angle is incremented by 0º 30' 0" and then conducted reading staff simulation till getting the closest distance to the O – B distance. The similar simulation is conducted 40 times.



Gambar 3. Perhitungan jarak datar Alat (O) ke Stake Out (B)

The 40s reading simulation gives the average of distance 25.460 m

The computation result of horizontal distance of O – B (25.461) will become standard value (R_{true}), it is the theoretical distance between instrument and stake out point, and the measured distance or optical distance (Ri) that is resulted from staff reading and vertical angle use formula 3 and 5.

Hence the precision of horizontal measurement can be determined based on deviation standard using formula 6.

$$E_{pre} = \sqrt{\frac{1}{40}\sum_{i=1}^{40} (R_i - 25.460)^2}$$

E_{pre} = 0,029 m

And value of Relative Deviation Standard (RDS) is

RDS = (0.029/25.460)x100%,

Precision = 0.12%.

And the accuracy of horizontal distance measurement is determined by formula 7 as follow:

$$E_{acu} = \frac{1}{40}\sum_{i=1}^{40} (R_i - 25.461)$$

E_{acu} = 0,025 m

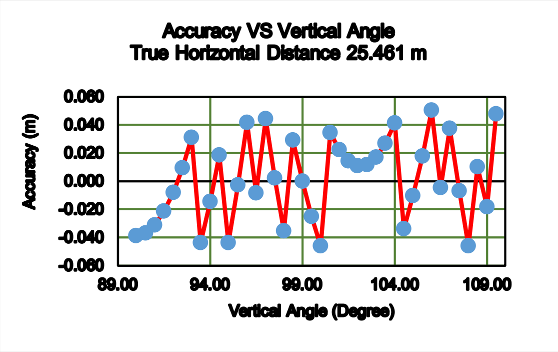


Figure 4. Distribution pattern of inaccuracy theodolite in horizontal distance of 25.461 determination with vertical angle between 90° – 110° incremented by 30'.

Figure 4 shows 40s experiments with different vertical angle (90° – 110°) the theodolite accuracy in the determination horizontal distances is 0 – 0.05m. in that scatter graphic distribution of accuracy has no direct correlation to the vertical angle increment. In these experiments prove that the distance measurement accuracy of theodolite has higher accuracy compared to the previous study which was conducted by Gill and Aryan (2016) which stated that digital theodolite has accuracy in distance measurement between 0.3m – 0.2 m. On the scatter graphics inaccuracy in minus value shows that the results of measurement less than standard value and vice versa.

In the real field measurement, the precision and accuracy of horizontal distance measurement can be increased caused by the operator's ability to read the staff and improper instrument setting above the predefined coordinate point. The problem of the inaccuracy of theodolite in determining the horizontal distance in stake-out measurement can be minimized by measurement using a ruler in the field start from staff face position of stake-out point backward or forward as the information that given by Stake Out Guide App. The second solution surveyors are able to use laser meter rather than using telescope

CONCLUSIONS

The result of the simulation of measurement and determination horizontal distance 25.461 m using theodolite with vertical angle 90° – 110°, so that the precision of horizontal distance is 0.12% and the accuracy is 0.025 m. The inaccuracy of horizontal distance measurement using theodolite can be minimized by adding ruler measurement from staff face to the predefined stake-out location. The implication of this research is that theodolite can be used to stake measurement in construction as long as it combined with other measurement such as ruler, roll meter in order to find the exact position of the stake-out point.

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