FORESTRY IDEAS, 2011, vol. 17, No 2 (42)

# STUDY OF THE RELIABILITY OF DISTANCES MEASURED WITH A REFLECTORLESS TOTAL STATION WITHIN FOREST LAND SURVEY, USING DIFFERENT TYPES OF MATERIALS-TARGETS

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UDC 630.5

Received: 13 May 2010
Accepted: 10 December 2011

## Abstract

Distance measurements feature an inextricable section of applied forestry science from the Forester engineer and concern a great variety of technical procedures. In nowadays the technological explosion of surveying instruments make these measurements a matter of seconds and even faster. Also, new alternative measurements are considered, such as reflectorless measurements, a function that is offered by most geodetic total stations. The range and accuracy of this function type is different and depends on the type of the total station. However, not sufficient attention has been given to the many error sources contributing to the uncertainty of such measurements and especially the quality of each measurement. Among others, the type and the colour of the material are considered as very important parameters for errors in distance measurements. The aim of this study is to determine the influence of the type of the material and colour to the quality of distance measurements using the total stations reflectorless ability. Therefore, experiments were carried out using 8 different types of materials or colours and Trimble 5605DR$^{+}$ long range total station.

**Key words:** distance measurements reliability, forest land survey, reflectorless total station.

## Introduction

In everyday scientific and professional activity of forester engineer, the surface distance measurements are a very important part of the Applied Science of Forestry for a wide variety of complex technical projects and processes such as, forest cadastre, surveying, forest alignments and torrent control works, roads, reforestation, rehabilitation of quarries, geodata collection for forestal and environmental studies, and others. The rapid technological development of surveying instruments, allows the development of new alternative methods of distance measurements, based on the possibility of measurement without using a prism reflector, which is very useful and even necessary in some cases, in the difficult and complex mountainous forest environment. The major advantages of reflectorless distance measurement are (Amann et al. 2001, Fidera et al. 2004, Lambrou and Pantazis 2006): 1) Ability to measure points which are inaccessible or very difficult to approach or with high risk to approach, points (slided embankments, quarries and mines); 2) Possibility to measure points in low light environments; 3) Possibility to measure points in monuments – protected areas without any damage; 4) Reduction of staff which perform measurements; 5) Reduction of measurement time and considerable precision in points detection.

## Material and Methods

The process of measurements took place outdoors in premeasured control points created to adapt the experiment. The measurements were conducted under good conditions, with visibility >20Km, slightly overcast, no heat, moderate wind and ensured direction of the sun i.e. sun was not opposed. Also, knowing the nominal value of the distance and in combination with forced centering both total stations body and targets, the results are directly comparable. The procedure for each set of measurements is as follows: a) Total station is placed in the first control measured point, and in the second point the tripod with the special support base of material-targets, which is placed under a forced centering and on which are placed the prism and all the material targets; b) the distance between total station and the prism is measured with the precision provided by the station for this specific measurement; c) the body of total station remains stable without changing the target angle in order the measuring conditions for each material to remain constant. Therefore, the point of distance measurement remains stable, and hence, different results are directly comparable; d) all the targeted material are placed at the same point measured with prism.

Thus, five successive distance measurements were conducted, in eight different materials, and the surface of the specimens forms an angle in respect to the direction of sight line of instrument body $90^o$, $30^o$, $45^o$ respectively. The change of target angle position was achieved by rotating the bases plate in their respective angles. This allow us to study the reflectivity of laser beam when the material is aimed not only at a vertically angle, which is often happens in reality (Boehler et al. 2003; Ingensand et al. 2003). It has to be noted that in all cases the instrument body was still encased in a stationary horizontal and vertical angles respectively.

The aim is to compare the value of the measured distance using a prism in each location with the one that was measured in the same position on the surface of each material and calculate their difference. This way allow us to examine whether the difference in distance measurement between total station and material target, with and without reflector, is more or less than the permitted 95% confidence level according to the measurement accuracy given by the manufacturers of institutions (Dermanis and Fotiou 1995, Rossikopoulos 2001). According to the above, $\Delta D$ is defined as the difference in the distance measurement with or without the use of reflector: $\Delta D = \beta_1 - \alpha_1$ – (1) where: $\beta_1$ measurement with reflector and $\alpha_1$ measurement without reflector. According to the law of transmission errors: $\sigma\Delta D = \pm\sqrt{\sigma\beta_1^2 + \sigma\alpha_1^2}$ – (2). In order the price difference of $\Delta D$ length to be eligible, it should be between the time intervals $-z\sigma_{\Delta D} \leq \Delta D \leq z\sigma_{\Delta D}$ – (3) where z value 1.96 for linear control for 95% confidence level. The audit was carried out for each material and each viewing angle.

In order to compare the reflector measured values with the one measured with the prism, specimens should be placed in a suitable arrangement in order to meet specific requirements. For this reason we have used an adequate base of support so that the measurement surface of the samples lie in this vertical plane containing the vertical axis passing through the centering point of the base, where it is horizontal and therefore its identical with the measuring point where the prism is positioned on the special base (Balodimos and Stathas 1993).

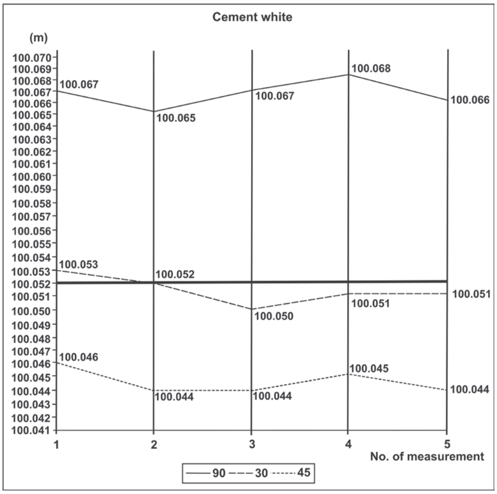
We have tried to cover a satisfactory range of materials and colors. Special attention was provided to materials which are considered ubiquitous in use and often encountered by forester engineer in the countryside. Some of these materials were collected in different colors in order to study the results of reflectivity of different colors of the same material (e.g. cement). Eventually, the following eight material with specimens dimensions 12 cm x 12 cm were selected and measured: 1) White Cement; 2) Cement Gray; 3) Rock; 4) Marble; 5) Iron; 6) Tile; 7) Asphalt; 8) Wood. All these materials were placed one after the other on the special support base and pegged in such a position so that the front surface of tangential links to the base and to implement correctly the vertical measurement. In order to perform the experimental measurements, the Trimble 5605RD+ total station is used and its special features are shown in Table 1 (Trimble 2003).

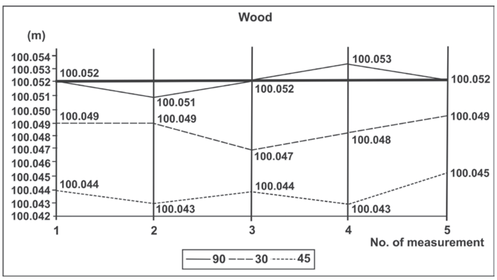
The experimental measurements were made in two distances, approximately 100 m and 400 m. The first one is a normal distance measured in the countryside, whereas the second one is resulted from measurements of laser beam divergence on a white board. Measurement that were conducted in distances larger than the second one, occur the fact that the imprint far exceeds from the size of the samples and

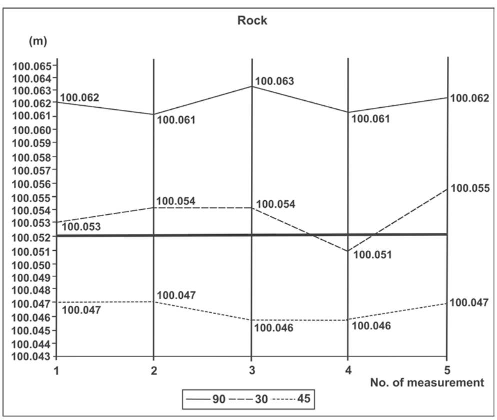
**Table 1. Total station specifications**

| | |
|---|---|
|  | TRIMBLE 5605RD+<br>Reflectorless ability.<br>Measuring time: 3 sec.<br>Weight: 6.6 kg.<br>Range: up to 600 m reflectorless, 2500 m using 1 prism and 5500 m for long distance measurements (long range mode).<br>Angle reading $1^{cc}$ and accuracy $\pm 15^{cc}$.<br>Distance measurement accuracy: standard, ±3 mm ±3 ppm with prism and ±3 mm ±3 ppm (<200m) and ±5 mm ±3 ppm (>200m) reflectorless.<br>Laser beam divergence 40 mm/100 m horizontal and 80 mm/100 m vertical. |

has caused serious problems in the measurements. The final precise distances in measurements with reflector were identified in 100.052 m and 400.140 m respectively.

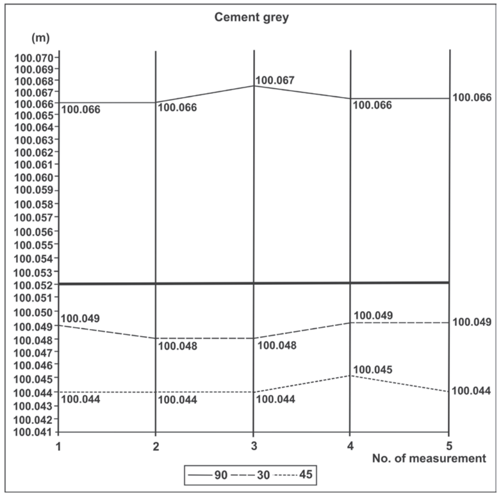


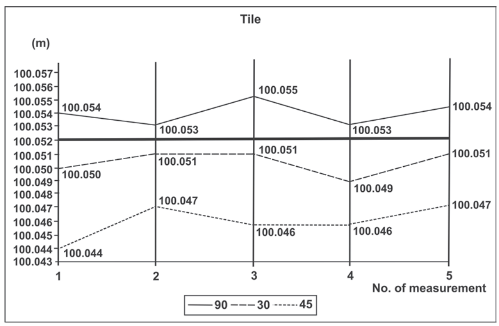



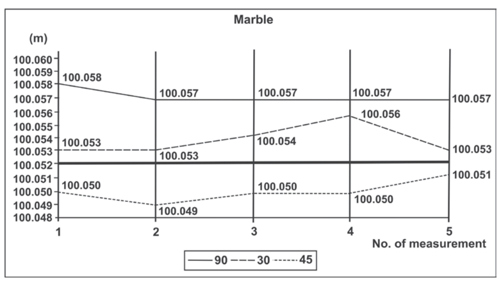




## Results and Discussion

The making of the experimental measurements has revealed the following results diagrams shown in Figures 1 and 2.



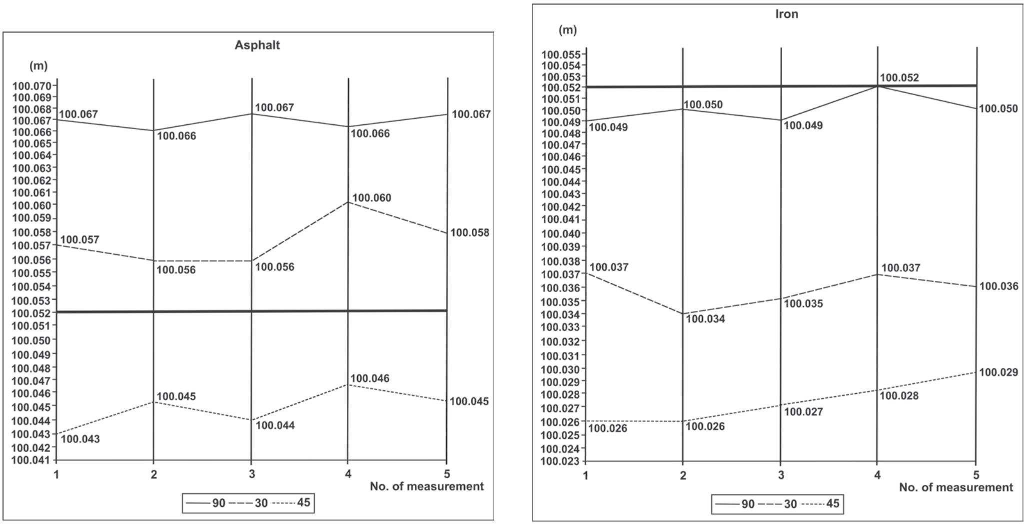



**Fig. 1. Graphs of distance measurements with Trimble 5605DR+ total station at 100.052 m.**

Then, tables for the evaluation and acceptance or rejection of the measurements have been set up. This way enables us to examine whether the difference in distance measurement between total station and target with and without reflector is acceptable for 95% confidence interval based on accuracies provided by the manufacturer. For Trimble 5605DR+ and according to the manufacturer the results are as follows: ±3 mm reflector and ±3 mm without reflector for measured lengths <200 m, and ±5 mm without reflector and ±3 mm reflector for lengths> 200 m. Thus, according to the equation 3, $\sigma\Delta D = \pm 4.2$ mm and finally to accept a measure of confidence level of 95% where $z = 1.96$, $z \cdot \sigma\Delta D = \pm 8.2$ mm, lengths while >200 m, $\sigma\Delta D = \pm 5.8$ mm and $z \cdot \sigma\Delta D = \pm 11.3$ mm. Table 2 shows the aggregated evaluation results of the measurements. Hence, the bold italic figures shown in the table are measurements that are not accepted within 95% confidence interval, the gray cell of the table show the measurements that except the fact that they are not accepted, they have presented large deviations compared to the originally measured with prism along, and symbol (-) indicates the impossibility of measurement.

Analyzing the results of the measurements we see that at the distance of 100 m all the material-targets are measured whereas in the 400 m distance was only four are measured. In the final two distances most of the conducted measurements were accepted at a confidence level of 95%. Especially in the 100 m 4 sightings out of 8 were accepted in the angle of 90° and 7 out of 8 in a angle of 30° and 45° respectively. In 400 m distance only one of all final measurements was not acceptable at a confidence interval of 95%, concerning the white cement at an angle of 90°.

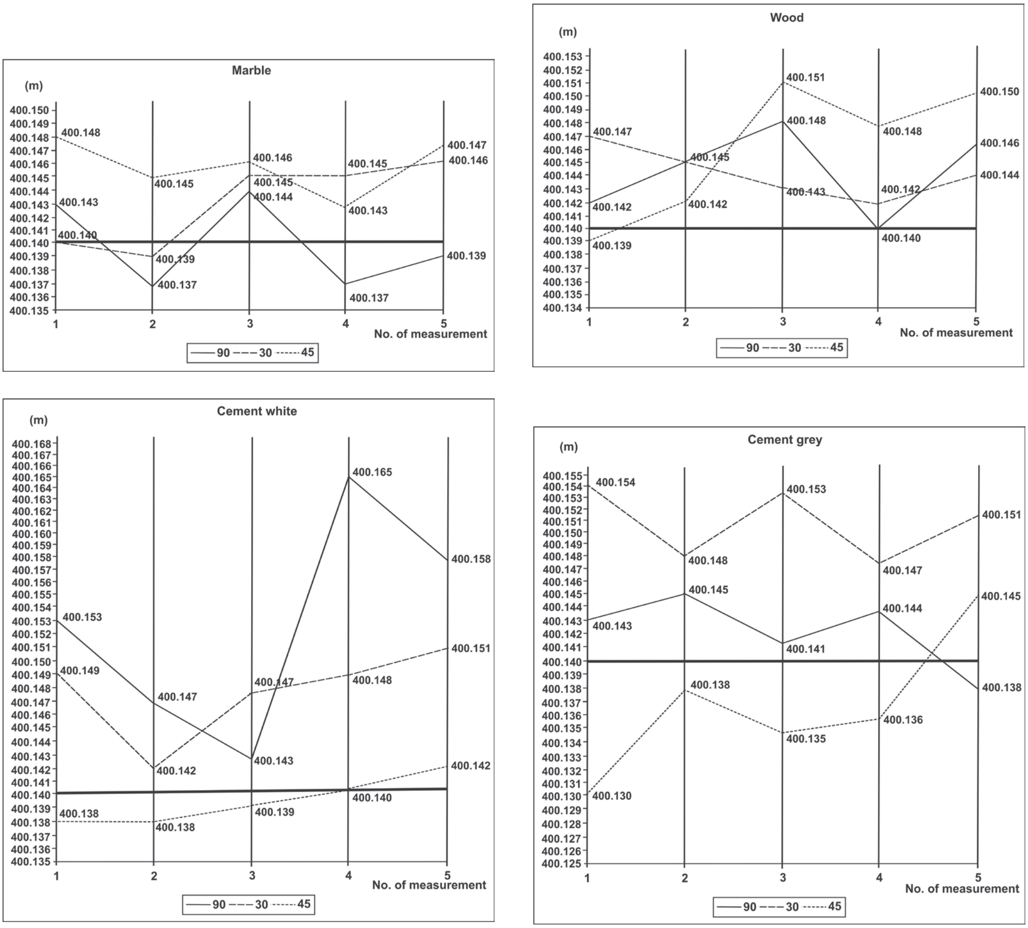



**Fig. 2. Graphs of distance measurements with Trimble 5605DR+ total station at 400.140 m.**

Also, while the target turns from the vertical angle, the distance value measured becomes less than the reflectorless measurement, which indicates that the angle of incidence is an important and decisive factor for the quality of measurements. The color is an important factor in the quality of measurements too. Generally colored materials have in general higher quality and more stable measurements. The texture and surface roughness of materials also affects the measurement results. Especially at a distance of 400 m, materials with a rough surface i.e. rock, asphalt, etc. either they made the measurements complicated or they were not measured at all. More measurements show a range of variation for both distance measurement 0–24.6 mm. The maximum difference was observed by measuring the distance value of the one measured with reflector in 100 m: 1) angle of incidence 90$^o$: 14.6 mm (cement gray, asphalt); 2) Turn on

**Table 2. Measurements evaluation with Trimble 5605DR+ total station.**

| | | Distance: 100.052 m | | | Distance: 400.140 m | | |
|---|---|---|---|---|---|---|---|
| | | ΔD, mm | ΔD, mm | ΔD, mm | ΔD, mm | ΔD, mm | ΔD, mm |
| **A/A** | **Material** | **90°** | **30°** | **45°** | **90°** | **30°** | **45°** |
| 1 | Cement white | ***-14.6*** | 0.6 | 7.4 | ***-13.2*** | -7.4 | 0.6 |
| 2 | Cement grey | ***-14.2*** | 3.4 | 7.8 | -2.2 | -10.6 | 3.2 |
| 3 | Asphalt | ***-14.6*** | 5.4 | 7.4 | – | – | – |
| 4 | Iron | 2.0 | ***16.2*** | ***24.8*** | – | – | – |
| 5 | Wood | 0 | 3.6 | 8.2 | -4.2 | -4.2 | -6.0 |
| 6 | Tile | -1.8 | 1.6 | 6.0 | – | – | – |
| 7 | Rock | ***-9.8*** | 1.4 | 5.4 | – | – | – |
| 8 | Marble | -5.2 | -1.8 | 2.0 | 0 | -3.0 | -5.8 |

30°: 16.2 mm (iron) 3) 45° move: 24.8 mm (iron). Similarly for the distance of 400 m were: 1) incidence 90°: 13.2 mm (cement white); 2) Turn on 30°: 10.6 mm (cement gray); 3) Turn on 45°: 6.0 mm (wood). For the distance of 100 m, best materials were wood, tile and marble and worse was cement gray, asphalt and iron. Similarly, for a distance of 400 m best material was marble and worse was cement white.

Utilizing on the conclusions drawn from all the experimental measurements and their effects on the use of these data and the further analysis of the status of reflection of a laser beam of modern total stations the following are proposed: a) To investigate the performance of the total stations reflectorless property at distances of 10 m by 20 m or so, in order to identify more precisely those distances from which the measurements can vary widely; b) To investigate the performance of total stations in the same material for different colors, so that to highlight the importance of color as a factor in the measurement and in return the same color for different materials to highlight the importance of such material as a factor affecting the measurements; c) To investigate the performance and reliability status of reflectorless total stations and specialized tests that are of particular interest as tariff measurements in various types, color, age bark roughness and forest species, different color, roughness and moisture and secondary wood products (chipboard, plywood, melamine, MDF, etc.), measurements on bare rocky and vegetative earthen embankments, with different types of rock and vegetation, respectively; d) To monitor the performance status of reflectorless property, total stations in experiments concerning the shooting at edges or sides of geometric elements, intersections levels, etc. and especially useful measurements on technical projects in rural areas (retaining walls, bridge abutments, culverts, buildings etc.); e) The application of experimental measurements to be made on actual field conditions and in different weather conditions.

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