Trimble Robotic Total Station 5600 SeriesDR200+ at staging area with material samples in background.

Direct Reflex vs. Standard Prism Measurements

Upon reading Mr. Pepling's product review of the Spectra Precision Focus 10 in the October 2008 issue, I took notice to one of the paragraphs on page 52. Mr. Pepling, and hopefully others, thought it would be interesting to see the results of a test comparing traditional prism measurements to reflectorless measurements using different materials at different angles to the line of sight. After reading the article I thought to myself that I had done something very similar for my senior project at New Jersey Institute of Technology in the Spring of 2007 and since I gained some useful information out of the project perhaps others would also.

The title of the actual project was *Final Report to Compare Direct Reflex Measurements to Standard Edm Measurements.* Essentially, the project was to complete a series of tests comparing prismless EDM measurements to the standard EDM measurements. The instrument I utilized for this experiment was the Trimble 5600 DR200+, circa 2001. The comparison test was performed using various materials of different textures from three different distances. The materials chosen were wood, vinyl, brick, concrete, asphalt and metal with distance intervals of 100', 200' and 400'. Upon completion of the tests I gathered sufficient data to compare the manufacturer's specified accuracy of the prism less measurements to that of the test measurements.

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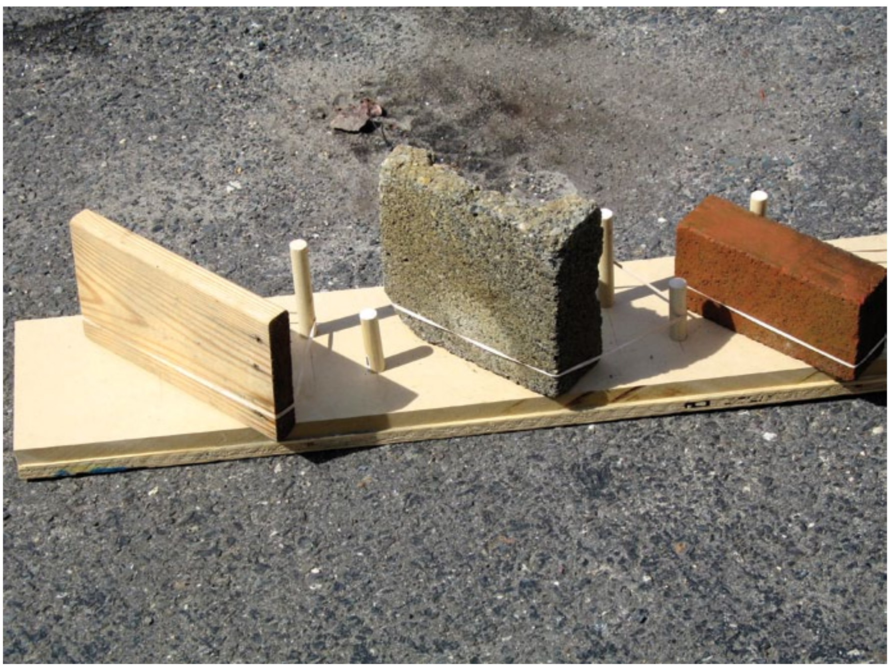
Material sample arrangement at 90-degrees to line of sight.



Material sample arrangement at 45-degrees to line of sight.

Upon completing the project I was convinced of the viability of using Direct Reflex technology for the everyday field surveyor. At the time I hoped the successful completion of the measurement tests would increase the professional land surveyor's confidence in this relatively new technology. Perhaps the surveyor's faith would be further reinforced by the use of common materials/surfaces encountered in the normal day to day surveying practice. Upon completion of the experiment I was happy to report that all these wishes had come true.

Before I get into the data and final comparisons of the project, I will attempt to briefly explain the two distinct types of direct reflex technology: Phase Shift and Pulsed Laser, commonly known as Time of Flight. Phase Shift works by modulating a signal onto a carrier wave signal which is similar to the way music is modulated for broadcasts over the radio. Essentially, modulated light measures a phase shift which will give a distance once a cycle ambiguity is resolved. Time of Flight works by measuring timing information to calculate a distance. Many short laser light pulses are sent out from the instrument to the target where they are reflected off and sent back. The round trip time of each of the laser light pulses are used to calculate the distance to the object. There are about 20,000 laser light pulse measurements every second which are averaged to display an accurate measurement value. The Phase Shift method is more accurate, up to ± 1 mm + 1 ppm as compared to ± 3 mm + 3 ppm for the Time of Flight method. On the other hand the Time of Flight method can measure much longer distances, with or without a prism and is more tolerant of line-of-sight interruptions than the Phase Shift method.

The Trimble 5600 DR200+, which is the chosen instrument for this project, uses the Time of Flight method.

The test surfaces/materials used for the experiment were wood (no finish), vinyl (neutral color), brick (red), concrete, asphalt and metal. These are common materials that seem to be most often encountered in the field.

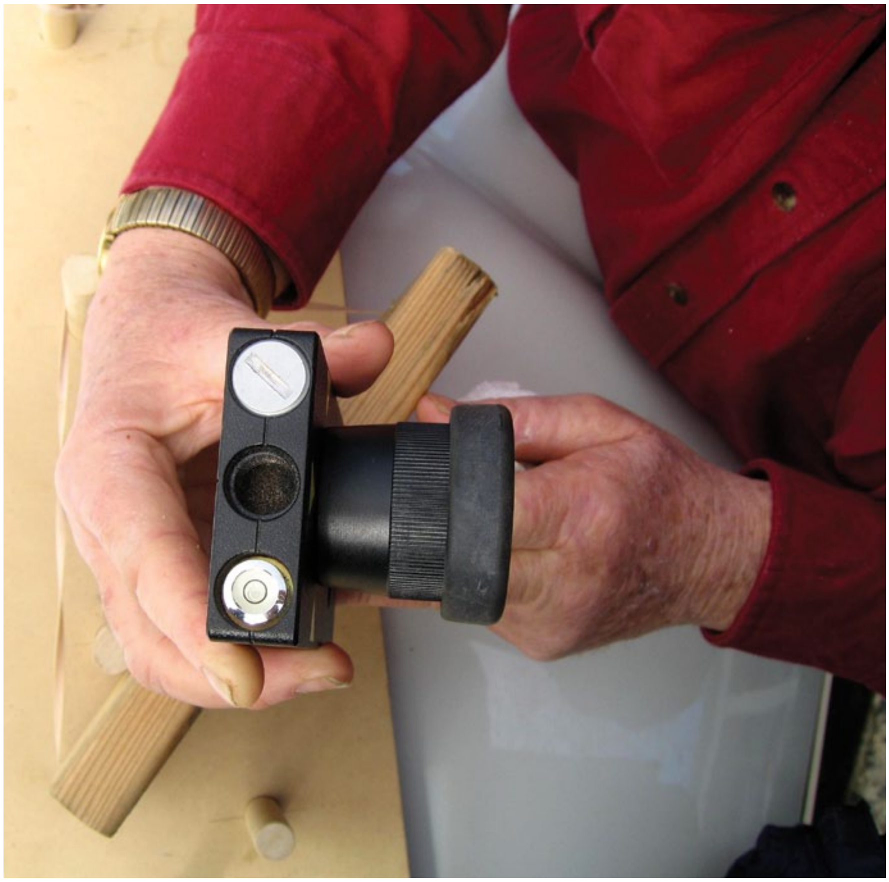
Procedures

1. Layout the three test distances of 100', 200' and 400' with a steel tape in order to setup material holders.
2. Position all six different materials on the first distance holder (100') insuring stability.
3. Recheck level of instrument, check temperature and pressure and set values in the instrument.
4. Have skilled assistant hold prism against surface to measure. Actual measurements will be that measurement plus the distance to the back of the prism. Using this technique will help to eliminate any error introduced by not holding the prism plumb over the face of the material to be measured to.
5. For the 100' distance interval a series of 10 distances were measured to each of the selected materials facing at an approximately 90-degree angle to the line of sight. Then a series of 10

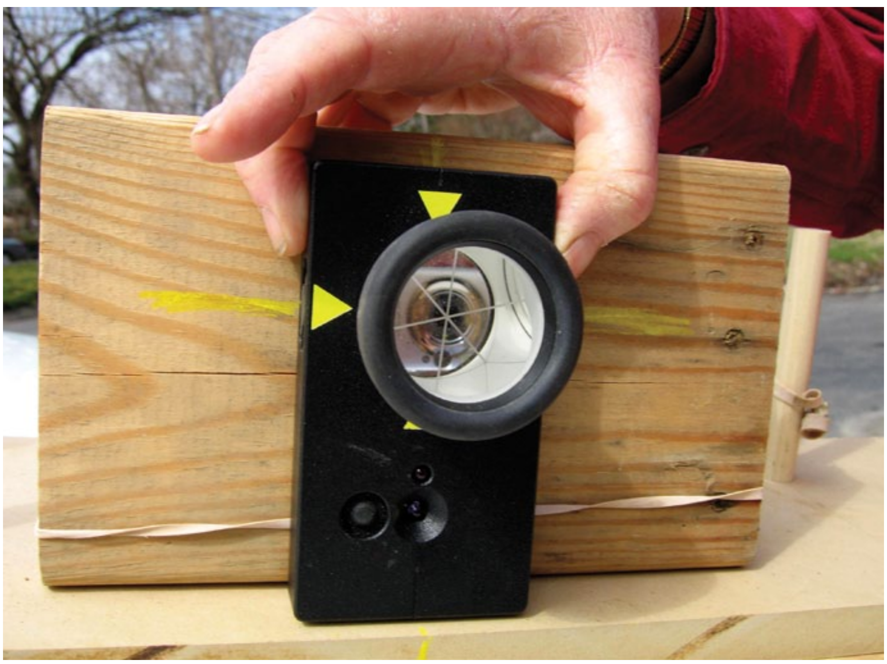
Direct Reflex distances were measured to the material faces. Then each material was placed at an approximately 45-degree angle to the line of sight and the procedure repeated. As this will give data on how the Direct Reflex distances handle surfaces that are not perpendicular to the line of sight, which is a common occurrence in normal field operations.

6. The procedures set forth in items 2, 4 & 5 were then repeated for both the 200' and 400' intervals.
7. Upon completion of the field experiment the data was then downloaded to the computer for comparison and analysis.
8. The control data was the series of 10 standard EDM measurements to each material at two different angles and three different distances. These averaged data sets represented the "true value" of the actual distance to each material.

The results of the experiment show the comparison of the achieved accuracy with the Direct Reflex measurements versus that of the manufacturer's stated accuracy.



Standard prism shot at 45-degrees to line of sight.



Standard prism shot at 90-degrees to line of sight.

Initially I was going to use a sample size of 20, but after some initial test measurements I did not get any different results as a sample size of 10. For that reason and due to time constraints, my analysis was based on a sample size of 10. I still handled more than 700 measurements for this project. Furthermore, a sample of 10 is also two more additional measurements than what the formula for a sample size yielded (see Notes).

Problems Encountered

Initially the metal material gave some very erratic measurements at the 100' interval even after several repetitions. The metal also gave the worst measurement results at the 45-degree angle for direct reflex at the 100' and 400' intervals. I was surprised at this because this material is the most reflective of the ones chosen. Also, the time for a direct reflex shot to register took much longer to the metal and the asphalt especially at the 400' interval.

Results and Conclusions

Trimble's stated accuracy for the instrument used for this test in the Direct Reflex mode to an 18% reflective Kodak Gray Card at a perpendicular to the line of sight is ± 3 mm + 2 ppm or ± 0.0102' @ 100', ± 0.0104' @ 200' and ± 0.0108' @ 400'. These stated accuracies were compared to the difference obtained between the aver-

Figure 1: Comparison of 90-degree Measurements to 45-degree Measurements

Manufacturer's specified accuracy to an 18% reflective Kodak Gray Card at a perpendicular to the line of sight = ± 0.0102' @ 100', ± 0.0104' @ 200' and ± 0.0108' @ 400'.

MATERIAL	"TRUE VALUE"	DIRECT REFLEX	DIFF.	"TRUE VALUE"	DIRECT REFLEX	DIFF.
BRICK@100'	99.99982'	99.99056'	0.0093'	100.1243'	100.1472'	-0.023
BRICK@200'	199.8599'	199.8555'	0.0044'	200.0024'	200.029'	-0.027
BRICK@400'	400.4902'	400.4837'	0.007'	400.7044'	400.6909'	0.014'
WOOD@100'	100.1362'	100.1295'	0.007'	100.2511'	100.2792'	-0.028'
WOOD@200'	200.1863'	200.1774'	0.009'	200.0783'	200.0922'	-0.014'
WOOD@400'	400.5386'	400.5391'	-0.001'	400.6141'	400.6365'	-0.022'
CONC.@100'	100.2434'	100.2425'	0.001'	100.2183'	100.2343'	-0.016'
CONC.@200'	200.1324'	200.1223'	0.010'	200.0867'	200.0879'	-0.001'
CONC.@400'	400.5749'	400.5411'	0.034'	400.6856'	400.6646'	0.021'
ASPHALT@100'	100.0505'	100.0467'	0.004'	100.212'	100.2216'	-0.009'
ASPHALT@200'	199.9234'	199.9106'	0.013'	200.0751'	200.0823'	-0.007'
ASPHALT@400'	400.488'	400.4777'	0.010'	400.6436'	400.6477'	-0.004'
VINYL@100'	100.2546'	100.2517'	0.003'	100.1608'	100.1888'	-0.028'
VINYL@200'	200.0704'	200.0628'	0.008'	200.017'	200.0312'	-0.014'
VINYL@400'	400.4035'	400.412'	-0.009'	400.5773'	400.5362'	0.041'
METAL@100'	99.99373'	99.98819'	0.006'	100.1489'	100.7508'	-0.602'
METAL@200'	199.8472'	199.8429'	0.004'	200.0224'	200.0357'	-0.013'
METAL@400'	400.5037'	400.4957'	0.008'	400.6466'	400.5997'	0.047'

age of the standard EDM measurements and the averaged Direct Reflex EDM measurements and as can be seen in the following chart (**Figure 1**) the results were more than favorable.

Conclusions

Overall the materials all faired very well. As was expected, the 90-degree measurements did much better than the 45-degree measurements. This was due to beam divergence, where the beam of light spreads out the farther away it travels from its source. Therefore both types of direct reflex will have an error when measuring to corners, vertices and surfaces at very oblique angles to the line of sight, which were the 45-degree surface measurements. The error to the 45-degree surface could have been eliminated by measuring in the direct and reverse modes and thus that divergence could have been cancelled out. Also, the instrument is equipped with additional support programs to keep the accuracy within its limits even to oblique objects. Based on the difference between the mean of the 10 standard EDM measurements and the mean of the direct reflex measurements, for the 90-degree line of sight, 16 out of 18 (about 90%) differences met or exceeded the manufacturer's stated accuracy. Out of the two that did not meet the standard, one was within two-thousandths of a foot of the specified accuracy. Although the differences for the 45-degree line of sight did not do as well as the 90-degree line, they are in a range of only 0.013' to 0.047' (excluding the one outlier metal @ 100'), which is more than acceptable for what the average surveyor is going to use this technology for. Most important when analyzing these results, one must keep in mind that the stated accuracy is to a surface perpendicular to the line of sight, and that measurements to oblique objects will be affected by beam divergence no matter which direct reflex technology is used.

From past experience I have used direct reflex measurements for primarily inaccessible objects and dangerous situations, such as electric towers, roof eaves, roof peak heights, centerlines of busy roads and occasionally nearby structures for a building offset check. For these purposes I believe that being in a range of say 0.03' to 0.05' is usually sufficient, and as such, this technology seems more than acceptable. The majority of the test results exceeded what the makers of the equipment stated and this technology has yet to see its full use and potential. With proper care in the measurements, the right material, redundancy and an advantageous instrument position the Direct Reflex technology can be used for far more situations than the ones mentioned earlier. Situations where a greater accuracy is required than just some centerline road shots, perhaps locating anything visible without leaving the instrument setup is possible. After the completion of this experiment, my confidence in this technology has definitely been reinforced if not increased significantly.

Notes

A calibrated EDM is assumed to be used for this experiment. Distances to holding platform will be approximate as the absolute distance is not as critical as the averaged standard EDM distance. Although the Direct Reflex range capabilities of this particular instrument are about 1,900' to a 90% reflective surface and about 600' to an 18% reflective surface, the distances selected for this experiment were those that are commonly accepted as a normal range that the field surveyor would normally be comfortable working with. Although the formula used for a sample size (sample size=[(1.96 x's specified std. dev.)/desired margins of error]2) yielded an average sample size of about eight, I initially chose a sample size of 20 but then changed to a size of 10 because sample sizes below 30 are common in surveying practice. Additional information can be obtained from a paper entitled "Direct Reflex EDM Technology for the Surveyor and Civil Engineer," by R. Höglund and P. Large, located at: *www.amerisurv.com/PDF/Direct_Reflex_EDM_Technology_White_Paper.pdf*.

Christopher Ernst has a degree in Engineering Technology from N.J. Institute of Technology. He passed the New Jersey LS exam in October 2008, and has been employed at a small family-owned surveying business for 11 years.