POLITECHNIKA WARSZAWSKA
WYDZIAŁ GEODEZJI I KARTOGRAFII
KATEDRA GEODEZJI I ASTRONOMII GEODEZYJNEJ

No. 2 (87), 2009

RESEARCH CONTRIBUTIONS IN THE FIELD OF ENGINEERING SURVEYING WITHIN THE PERIOD 2007 – 2008

REPORTS ON GEODESY

WARSAW UNIVERSITY OF TECHNOLOGY
FACULTY OF GEODESY AND CARTOGRAPHY
DEPARTMENT OF GEODESY AND GEODETIC ASTRONOMY

A POST FOR PRECISION RESEARCHES OF MEASUREMENTS OF DISTANCES BY REFLECTORLESS TACHYMETER

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1. INTRODUCTION

Presently built and exploited engineer objects require using correct measuring methods and checked geodesy instruments. Geodesy conditions of which needs to be fulfilled at engineering objects in respect of technical regulations (norm PS/ISO, design requirements and geodetic instructions) place a duty on using techniques and geodetic technologies which allow defining coordinates of measuring points and controlled with precision established for the object.
At engineering objects, the most often used measuring methods of coordinates definitions a method of angle cuts, linear and angle-linear and polar are used. Carrying out of the method is connected with a use of a the set: electronic tachymeter with glass return reflectors, measuring foil or electronic tachymeter which allows reflectorless measurement. Companies which produce geodesy equipment set given precision parameters of an instrument but they do not define precision connection for their reflectorless tachymeters between the measured distance and a type of the aim (surface texture, color, spatial aim distribution, type of material, etc.).
From advertising materials of particular manufactures it comes out that the precision of measurement of distances with reflection from flat, even surfaces is 2 to 5 mm.
From up to date experiments of a use of tachymeters in inventory measurements turns out that there are problems with precision of measurements located on construction elements whose surface is not flat (corners of buildings, squares, object facture, etc). Apart from that, color of the object, size of the object and the angle the measurement is taken influence precision and range of measurements. The authors, noticing a lack of such deliberations, have attempted to elaborate and manufacture an universal test stage which would allow to perform distance measurement with mirror less tachymeter in conditions close to those during measurement on the object.
The authors have attempted to elaborate and performing a universal test stage which would make taking measurements by reflectorless tachymeters possible , in conditions close to conditions occurring while taking measurements on the object.

2. BUILDING OF A SIMULATOR OF A UNIVERSAL STAGE

A view of a universal test stage has been presented in fig. 1. It allows one to simulate the situation of aim placement in space in such a way as it is seen during observations made on engineering objects. Additionally the stage is fit with a tightening grip which makes seating possible for the period of performing the tests used for various reasons.

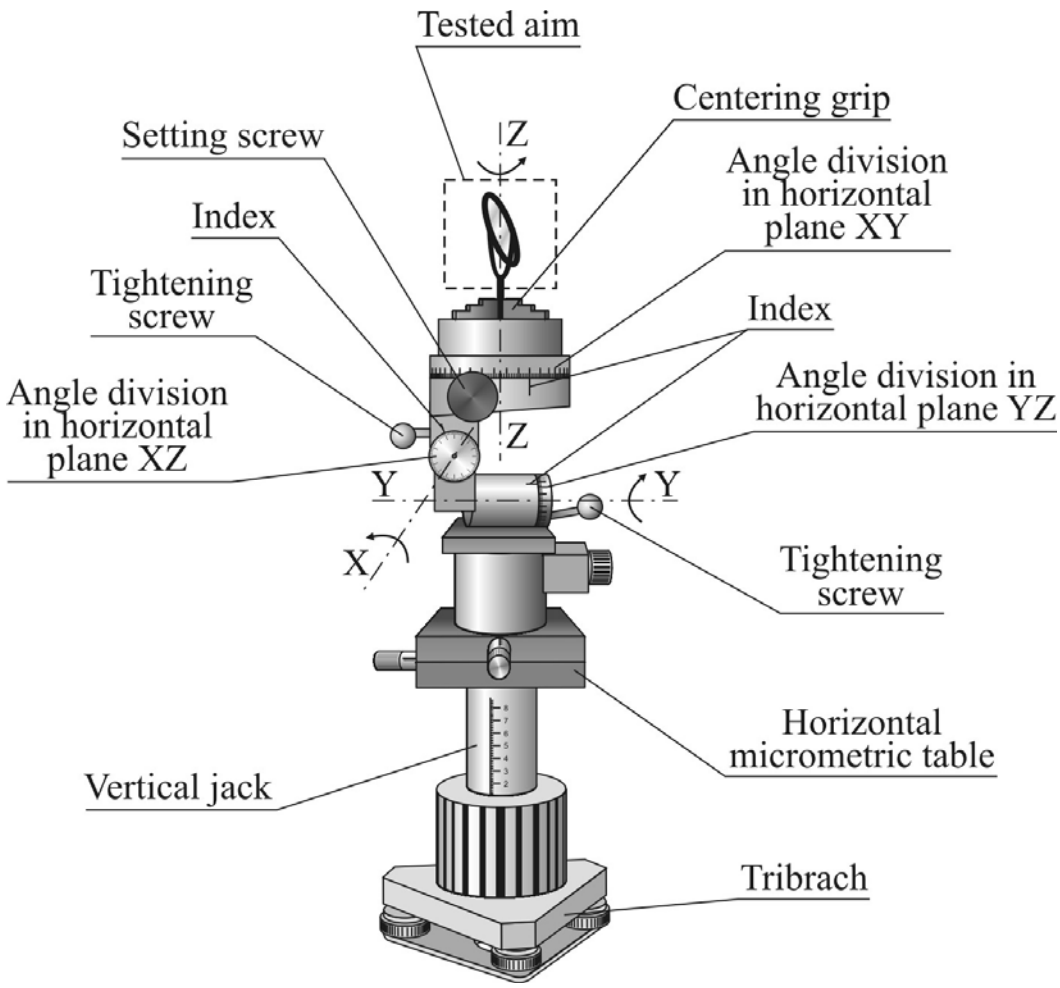

Fig. 1. Building of a universal test stage.

Simulation of aim location in space relies on its deviation from the vertical line, rotation around vertical axis and horizontal and vertical displacements. Displacements, rotations and deviations of a tested aim can be freely asked and read.

3. EXPERIMENTAL WORK

A project has been elaborated by the authors for proceeding with planned type of experiments and next presented in fig. 1, 2, universal simulation table was performed in a form of a prototype. For test researches, a popular electronic tachometer TCR407 Power of average precision class (fig. 3).

Fig. 2. A prototype of a universal simulation table on a measurement post.

Fig. 3. Electronic tachometer Leica TCR407 power on an observation post.

Experimental works run on a distance base and in laboratory of geodesic techniques. They were to check in what range the laser beam changes in function of distance and how the change of distance influences the precision of measurement of distance for various types of measured surfaces. Reflecting measurement surfaces were diverse as far as colour, texture and type of material were concerned (fig. 4, 5, i 6). Also checked was in what way a change of inclination angle of a reflecting surface influences the precision of observation results.

The range of change of laser beam which shape is close to ellipse is presented in table 1 where approximate values of both axis were given.

Table 1. The range of change of laser beam

Distances	Values of semi-axis of laser beam ellipse (semi-axis horizontal × semi-axis vertical)
[m]	[mm]
20	4 × 4
40	4 × 7
60	5 × 8
80	6 × 10
100	7 × 12

Correct definition of the size of a laser beam for changes in measuring distances has vital importance in measurements to small or angle construction elements of objects. In those cases, the location of aiming place is very important. It has to be done in such a way that maximally the biggest part of sent laser beam (the best would be the whole of it) reflects from the measured surface.
Research on the influence of roughness of reflecting surfaces on the precision of the distance measurement were run in a base located in geodesy laboratory. Test distances were measured among four poles, for signals covered with surfaces reflecting with various roughness. For comparison, measurements to a mirror (D) where differences of measured distances were calculated in accordance to standard deflection (Δ_d). Each distance was measured 6 times for defining the standard deflection (m_d). Five various reflecting surfaces were used : first of a high roughness of light brown color, second, slightly rough in red colour, third slightly fluted in navy blue and two smooth in red and green. Results of measurements were presented in table 2.

Table 2. Results of distance measurements for signals of various roughness of reflecting surfaces

Marking of a side	Length of a side	Type of reflecting surface									
		Rough brown		Rough Red		Fluted navy blue		Smooth green		Smooth Red	
	D	Δ_d	m_d	Δ_d	m_d	Δ_d	m_d	Δ_d	m_d	Δ_d	m_d
	[m]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]
1 – 2	7,0630	+3,5	±0,5	+2,8	±0,4	+2,3	±0,5	+2,8	±0,4	+2,2	±0,4
1 – 3	5,6010	+2,8	±0,4	+2,7	±0,5	+3,2	±0,4	+3,6	±0,5	+1,3	±0,5
1 – 4	10,4400	+3,8	±0,4	+3,2	±0,4	+2,5	±0,4	+2,8	±0,4	+0,7	±0,5
2 – 1	7,0630	+4,2	±0,4	+3,3	±0,5	+2,5	±0,5	+3,1	±0,4	+2,2	±0,4
2 – 3	10,4560	+3,8	±0,4	+3,2	±0,4	+2,2	±0,4	+2,8	±0,4	+1,3	±0,5
2 – 4	10,6160	+3,3	±,05	+3,2	±0,4	+2,8	±0,4	+2,3	±0,5	+1,3	±0,5
3 – 1	5,6010	+4,8	±0,4	+3,8	±0,4	+3,2	±0,4	+3,2	±0,4	+2,7	±0,5
3 – 2	10,4560	+3,7	±0,5	+2,7	±0,5	+2,3	±0,5	+2,5	±0,5	+1,8	±0,4
3 – 4	7,0350	+4,8	±0,4	+4,2	±0,4	+3,8	±0,4	+3,5	±0,4	+2,8	±0,4
4 – 1	10,4400	+4,2	±0,4	+3,8	±0,4	+2,3	±0,5	+2,7	±0,5	+1,8	±0,4
4 – 2	40,6160	+3,5	±0,5	+3,2	±0,4	+2,8	±0,4	+2,8	±0,4	+1,5	±0,5
4 – 3	7,0350	+4,5	±0,5	+4,2	±0,4	+4,2	±0,4	+3,2	±0,4	+3,2	±0,4
	Average	+3,9	±0,6	+3,4	±0,5	+2,8	±0,6	+2,9	±0,4	+1,9	±0,7

Summing up the results presented in the table 2 it is stated that in each case distances measured for chosen surfaces are bigger than distances measured to the mirror. It is also stated that the rougher the surface is the longer the distance is. For all measured distances, similar values of measurement errors were gained (m_d), and differences of distance in respect of the mirror measurement (Δ_d) are not bigger than 5mm.
Researches of dependence of exactness of measurement on color and angle of the chosen reflecting surface were run in terrain base. Measurements of distances were run to the chosen reflecting surfaces which differ in color and structure of surface. The following surfaces were chosen: three with slightly rough surface in colors: yellow, red, dark grey, more rough surface in light brown color and surfaces from matt glass. Taking into consideration the real terrain conditions in measurements neither the smooth surfaces were not tested nor white surfaces which occur very rarely in natural terrain conditions. Angles of measurement rays onto reflecting surfaces were also changed, starting with straight angle and increasing the angle in following respect of 20 and 40 degrees. Measured distances were compared for measured to the mirror (Δ_d). Each distance was measured 6 times for achieving standard deflection (m_d). For defining approximate possible distance of measurement, distance were increased in accidental way. Results of measurements were presented in table 3.

Table 3. Results of distance measurements to signals of various colour intensity and whit changing angles of laser beam

Type of reflecting surface	angle 90^o (straight)		angle 110^o left		angle 110^o right		angle 130^o left		angle 130^o right	
	Δ_d [mm]	m_d [mm]	Δ_d [mm]	m_d [mm]	Δ_d [mm]	m_d [mm]	Δ_d [mm]	m_d [mm]	Δ_d [mm]	m_d [mm]
mirror 47,7138 m		± 0,4								
colour yellow	+2,5	± 0,5	+2,9	± 1,0	+2,7	± 1,0	+2,7	± 1,0	+ 3,4	± 0,9
colour red	0,0	± 0,5	-1,1	± 1,2	-1,3	± 1,4	- 4,3	± 1,0	- 2,6	± 1,5
colour gray	-0,8	± 2,0	-	-	-	-	-	-	-	-
colour brown	+0,2	± 0,6	-1,8	± 0,6	+0,2	± 1,1	+ 2,0	± 1,0	- 3,8	± 1,1
matt glass	-5,8	± 1,1	-	-	-	-	-	-	-	-
mirror 74,3807 m		± 0,5								
colour yellow	+2,8	± 0,6	+3,8	± 1,1	+ 4,6	± 0,8	+ 4,1	± 1,2	+ 3,9	± 1,5
colour red	+1,3	± 1,1	+3,0	± 1,5	+ 3,5	± 2,8	-	-	-	-
colour brown	+1,6	± 1,0	+2,8	± 1,8	+ 1,9	± 1,4	-	-	-	-
matt glass	-3,7	± 1,3								
mirror 99,2337 m		± 0,5								
colour yellow	+1,6	± 0,8	- 2,1	± 1,6	+3,8	± 1,0	- 4,7	± 2,5	+ 4,3	± 1,8
matt glass	-7,0	± 2,9								
mirror 124,9490 m		± 0,6								
colour yellow	+3,0	± 0,9	+3,8	1,0	+ 4,5	0,9				
matt glass	-7,3	± 0,5								
mirror 159,8852 m		± 0,4								
colour yellow	+8,0	± 3,1								
mirror 177,8978 m		± 0,4								
Unfeasible measurement										

Analyzing results presented in table 1 we have confirmed the fact that measurement possibilities (range) depends on degree of color saturation of reflecting surface , when the color is lighter the range is bigger. This range gets smaller together with increase of the angle between aiming line and reflecting surface. In such case also observation errors increase. In proposed article, the best results were gained with a use of yellow color where correct results were obtained at a distances of about 125 meters. For red surface and light brown correct results were obtained at about 75 meters. Huge range of measurements was obtained for matt glass (about 125 meters). however high differences in measured distances in respect to distances measured to returned signal was obtained, but refection of signal in case of turning the reflecting signals was not obtained. Small range of measurement was obtained for surfaces of gray color (about 50 meters), also in this case the signal in case of turning the reflecting surface was not obtained.

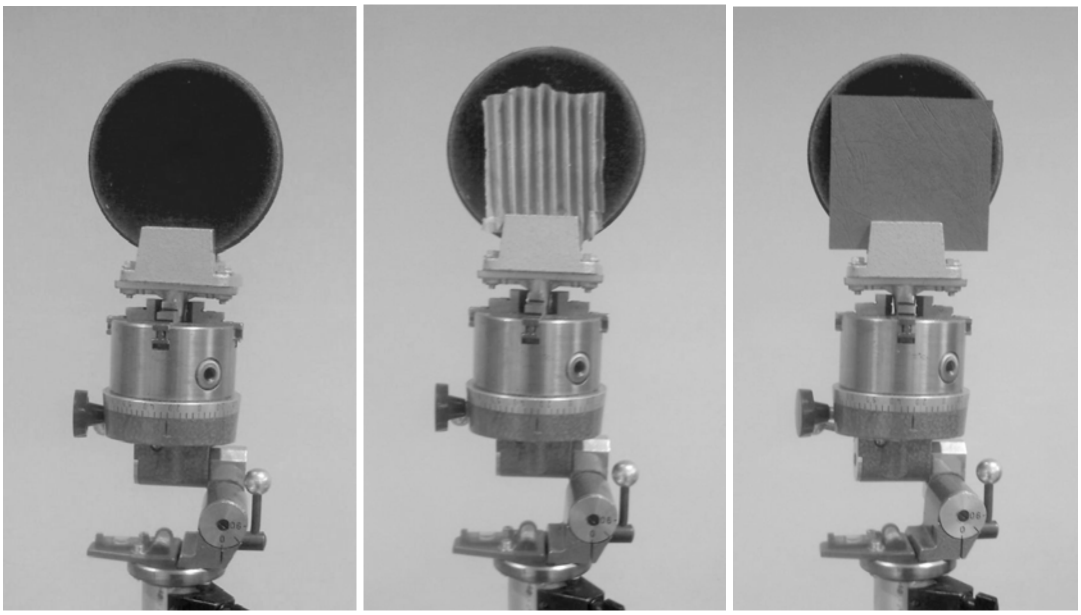

Fig. 4, 5, 6. Exemplary types of reflecting surfaces used in test researches.

4. SUMMARY

Instruments and devices offered by companies which produce geodetic equipment often require, especially in engineering objects, using additional aid equipment which allows widening observation possibilities.

The elaborated and constructed prototype of a universal simulation stage makes possible running test researches for measured surfaces which are characteristic for a measured object where distance measurements are to be made by a reflectorless tachymeter. Experimental researches confirmed usefulness of the stage for measurement - researches works.

Basing on the run experimental measurements, the following conclusions can be drawn:

1. **Places of aiming to construction elements of the researched object, we need to adapt to sizes and elliptic shape of laser beam.**
2. **Color and intensity of the color of a reflecting surface influences range and correctness of defining of reflectorless measured angles. More reliable results are concluded for surfaces of a lighter color and less rough surfaces.**

3. Change of the angle of defection of reflecting surfaces in relation to measuring beam in range +/- 20 degrees and even +/- 40 degrees does not lower precision of measurement (m_d), while the angle of aiming is rising also the differences of distance which are defined in relation to comparison distances (Δ_d). In the run experiment those differences did not exceed values of +/- 5mm.

It is necessary to state that obtained results of experimental measurements will allow to improve quality of performing observations by tachymeters carrying out reflectorless measurement.

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