REFLECTORLESS MEASUREMENTS ASSESSMENT OF THE SUITABILITY AND ACCURACY OF THE MEASUREMENTS

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1. INTRODUCTION

Measurement technics in geodesy have strongly intensified their development towards the remote methods of acquiring information in recent years. This trend can be observed for example with reflectorless measurement of distance, the method which is accessible in more and more of new tachymeters. Manufacturers compete with solutions that are able to provide larger range of measurement, while at the same time the accuracy of it is still adequate enough for majority of geodetic jobs. Unfortunately, the parameters that describe the reflectorless measurement published in the specification of the instruments refer to measurements, which were made in the strictly defined conditions, with the use of specific background materials, accessibility of which is hardly to repeat in the real, everyday work in the field.

2. THE GOAL OF THE RESEARCH

The goal of the research was to determine if the current capabilities of reflectorless distance measurements are able to meet the demands of surveying practices. Instruments are often exposed to very difficult working conditions, during which maintaining sufficient accuracy is required by the regulations or planning assumptions. One has to remember that those work conditions aren't the ones the manufacturer anticipated when the instrument's technical specification was created. Both the environment and the background material to which the distance measurement is performed often are strongly different from the technical specifications standards. In

addition, the beam incidence angle can have big impact to the results, due to the unperpendicularity of it, what occurs very often.

3. THE METHOD OF THE RESEARCH

To carry out the research four instruments were used: tachymeter TOPCON GPT 3005N – made available to us by the Military Technical University in Warsaw and three tachymeters: TOPCON GPT 3105N, TOPCON GPT 7503, TOPCON GPT 9003M – which were loaned by TPI company to conduct the research.
All chosen tachymeters have had the capabilities to perform the prism measurement as well as the reflectorless measurement.

The table below shows some characteristics of the tachymeters used in the research based on the manufacturer's technical specifications.

	GPT 3005N	**GPT 3105N**	**GPT 7503**	**GPT 9003M**
Measurement with the prism	3000m	4000m	4000m	4000m
Accuracy of the prism measurement	+/- (2mm+2ppm)	+/- (2mm+2ppm)	+/- (2mm+2ppm)	+/- (2mm+2ppm)
Reflectorless measurement	1.5-250m	1.5-350m	1.5-2000m	1.5-2000m
Reflectorless measurement accuracy	+/- 5mm	+/-(3mm+2ppm)	up to 250m: +/-5mm further then 250m: +/-(10mm+10ppm)	up to 250m: +/-5mm further then 250m: +/-(10mm+10ppm)

Tab.1. Distance measurement specification of the examined instruments.

During the research, the measurements were preformed according to the following rules:

- **4 measurement distances – 50, 150, 300 and 500 meters,**
- **5 measurements for: each distance, each background material and each incidence angle,**
- **measurements were carried out to the prism and then to 4 background materials**
- **3 incidence angles of the laser beam – 0, 30 and 60 degrees**

The measurements were performed along the street situated at the territory of Military Technical University in Warsaw, just opposite the no. 53 building. Nearby is the main building of the Department of Civil Engineering and Geodesy and the entrance from Radiowa Street.

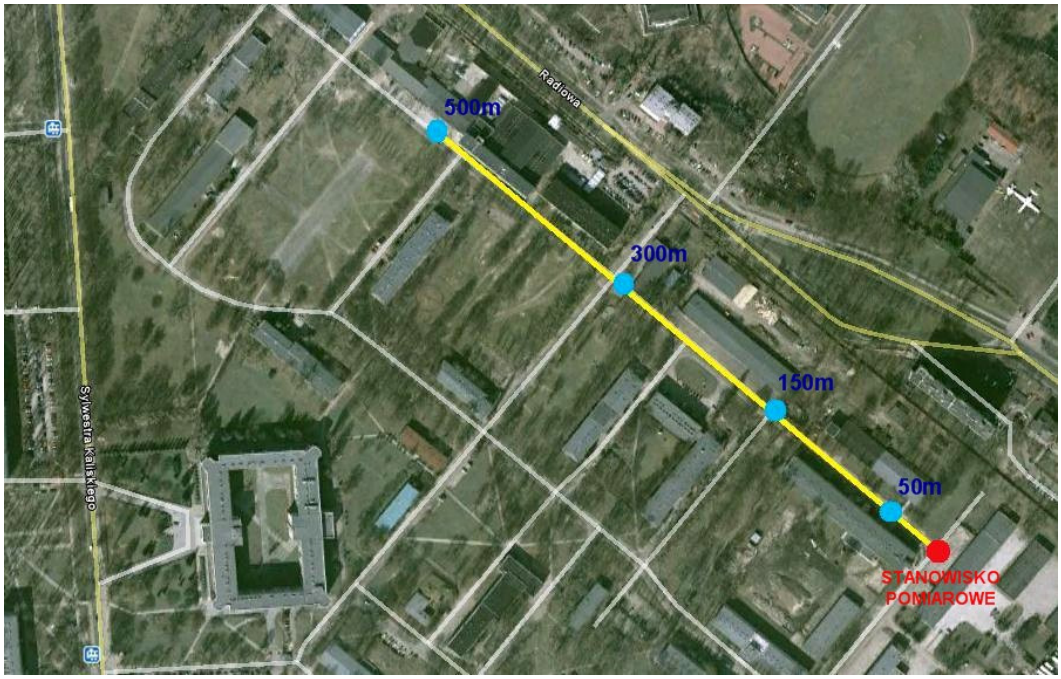

Fig. 1. Aerial image of the research area. Blue dots mark measurement distances, red dot marks the observation station.

The road was selected due to its exceptionally long straight section ideally suited to this type of measurements. The observation station has been situated at the one end of the road section, then at the distances of 50, 150, 300 i 500 meters the prism's tripods were established. The prisms have had specially designed and prepared plates mounted on its target boards.

Fig. 2. The target board with the terracotta plate.

At first the measurements were performed to the prism. Next the prisms were covered and the reflectorless measurement were conducted to the special plates mounted on the target boards. After that, the other rounds of surveys were carried out, each different from another because of the changed angle of the target board (30- and 60- degrees to the aiming line). Finally the target boards were switched to the ones with other background material plates and the whole procedure started again.

4. ANALYSIS OF THE RESULTS

During the research 4 instruments were tested and number of results for distance measurements were received. They have been compiled according to the following criteria:

- **CHART 1 shows changes to the absolute value of the difference between measured distance to the prism compared to the measured distance to the target board. The difference value is projected on the axis with measured distances. Incidence angle of the laser beam = 0˚.**
- **CHART 2 shows changes to the absolute value of the difference between measured distance to the target boards when the incidence angles of the laser beam are 0˚ and 30˚.**
- **CHART 3 shows changes to the absolute value of the difference between measured distance to the target boards when the incidence angles of the laser beam are 0˚ and 60˚.**

At the following pages there are charts for all of the examined instruments, gathered accordingly to the criteria mentioned just above.

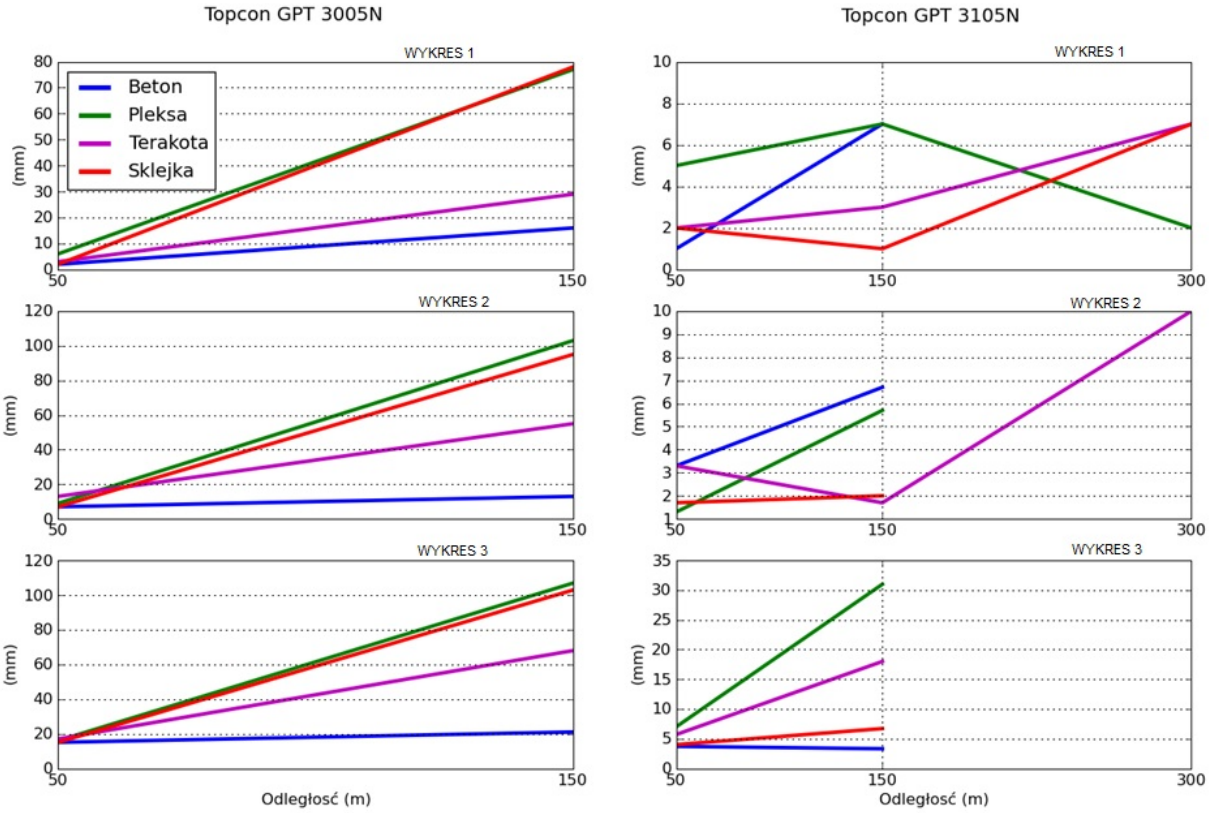

Fig. 3. Charts with the results for tachymeters TOPCON GPT 3005N i TOPCON GPT 3105N. Blue line correspond to the concrete background material. Green line correspond to the plexiglass, magenta to terracotta and red to plywood material.

Looking at the results for GPT 3005N instrument following opinions could be stated:

- **in every possible combination the range of the measurement was at least 150 meters what could be considered as a success given that the maximum range of the instrument is 250 meters and that the results of other instruments aren't sometimes much better,**
- **for every combination one can see a similar distribution of measurement results. Always the best effects were when the background material was a concrete, the worst cases always were the ones with plywood and plexiglass plates.**
- **initial deviation at the level of 20 mm changed up to 120 mm with increased distance. Such a deviation exclude this instrument from many geodesic works. This device could be used only at short aiming lines – only then the results will be acceptable.**

The GPT 3105N instrument has achieved strongly better results (smaller values of differences):

- **with the incidence angle at maximum (60 degrees) and aiming at the worst background material (plexiglass), the difference was 30mm. This value is four times smaller (better) compared to the previous instrument (the one which is at our disposal at Military Technical University in Warsaw).**
- **as it is mentioned above, the worst background material for this instrument was plexiglass. The best one was plywood which is quite opposite to the results achieved for the previous instrument.**
- **quite unexpected was also that the plywood plate again returned the worst differences (up to 45mm), while with the previous instrument it was only 5mm.**

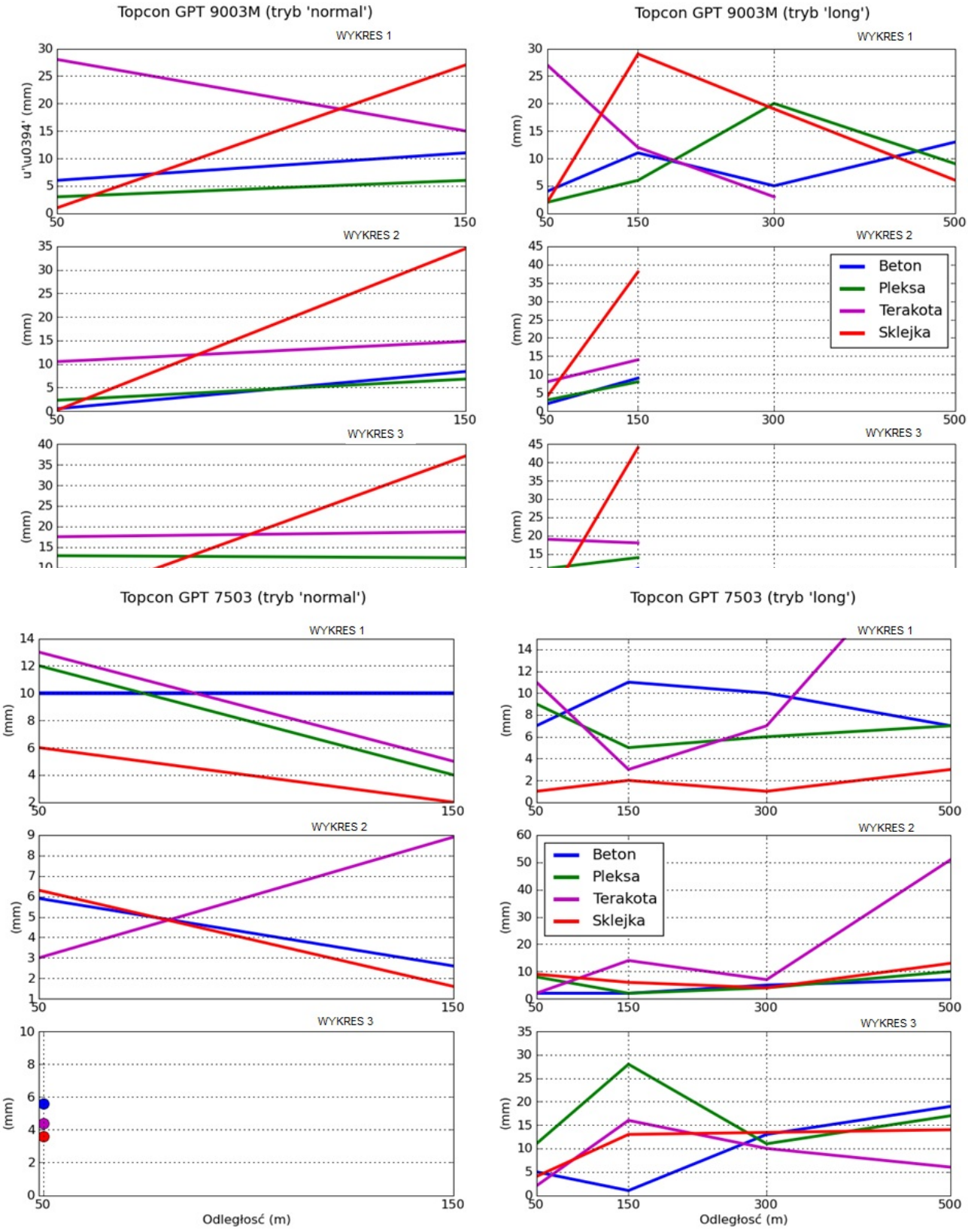

Fig. 5. Charts for tachymeter TOPCON GPT 7503 (meaning of the color lines is provided in the pic.3 subtitle).

Instrument GPT 7503

- **like the GPT 9003M model it is also equipped with two modes of measurement: the normal mode – up to 250 m and the long mode – further than 250 m**
- **the normal mode returned very poor results if the range is considered. At the incidence angle of 60° degrees the measurements were successful only at 50 meters distance. The worst results were observed for the plexiglass material which has allowed any measurements only with 0 degrees setup of the target board.**
- **the long mode (except terracotta material) returned positive outcome. Even with 500 m measurement distance the differences were only at the order of millimeters (when aiming at plywood with 0 degrees incidence angle). This instrument achieved the best results from all tested during the research.**

5. CONCLUSIONS

The distance measurement error is only one of many factors which have influence to the overall surveying result. As shown by the research the reflectorless measurements are very often not useful for precise geodetic tasks. Unfortunately some measurements shows that the permissible errors were exceeded also for features from the I accuracy class (buildings, roads, objects fixed to the ground) based on the technical guidance G.4. In such case the use of the instrument is forbidden to the majority of geodetic field works.

The results of measurements are highly related to the parameters of the given tachymeters (their distance measurement units). More stronger the signal is, the bigger aiming range is. However, the research has revealed that accuracy of it could vary depending on the particular instrument even if their parameters are similar. It means that each tachymeter need individual examination to determine its characteristics. The same examination is required for different background materials as the research clearly shown that the signal reflection could be errorful depending on the background material.

During the research, some problems with the distance measurements were encountered due to too wide beam size. It happened occasionally that at the longest distances the instruments were measuring objects that were even 2 meters out of the aiming line. In consequence the readings were wrong. Such situation could very often occurs at field so the observations should be always double checked.

In the future, with the research hopefully to continue, the authors aim to make the research method better, to examine more number of instruments (also from other manufacturers than Topcon) and to create the dedicated test procedure for reflectorless distance measurements of the electronic tachymeters.