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THE POSSIBLE USES OF RTN-SOLUTIONS FOR MARKUP WORKS ON CONSTRUCTION

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The purpose of the research. Elaboration of practical recommendations concerning creation of a geodesic markup construction base with GNSS technologies, including Real Time Networks (RTN) methods. **Methodology**. To investigate the accuracy of the recommended solutions, different kinds of research were made, including a practical one. It was conducted on the construction site by marking the axis from two base lines, previously indicated by a GNSS receiver in such a way, so they coincided with the x and y axes of the general site's plan. To minimize the sporadic errors and increase the accuracy of obtained results, the investigation was made on the inherent basis, which allows the forced centering of tools. The special aspect of this basis is that it is situated very close to the permanent station (10 km). This factor substantially compensates the systematic errors in the results of the relative measurements. **Results:** Results of the study are: it was established that when setting the fixing baseline with the dual-frequency GNSS receiver in the way its pointed coincide with the main axes of construction netting and the following marking of all the elements of the construction site toward this baseline, the required accuracy is provided, e.g. mutual location of points of main, basic, and detailed axes, and in some cases fitting axes as well. **Scientific novelty and practical significance**. The research presupposes using only the main axes of the construction netting and extend the marking networks of the site and construction. This method allows refusing from building the basic construction netting, by replacing the supporting geodesic network with two base lines (at least 4 fix points), that fix the location of the coordinates' axes of general site and controlling the axes marking by Total Positioning Station (TPS) method using the value measured by RTN for controlling the value of distances between the base lines points.

Key words: GNSS, TPS, RTN measurement, planning works, electronic total station.

Introduction

Global Navigation Satellite Systems (GNSS) are widely used during surveys, construction, and reference measurements together with the traditional methods. [Trevoho et al., 2016]. On our opinion, the most promising methods during the creation of the geodesic marking network are Real Time Networks (RTN) measurements (with reference stations networks), that are not even mentioned in the modern documents [DBN V.1.3-2-2010; DBN A.2.1-1-2014]. However, the advantages of RTN methods are more than obvious (measurements can be taken with one device, the results may be received without post processing just in seconds [Lanjo, Savchuk, 2012; Savchuk et al., 2009, Tereshhuk, Nystorjak, 2013]).

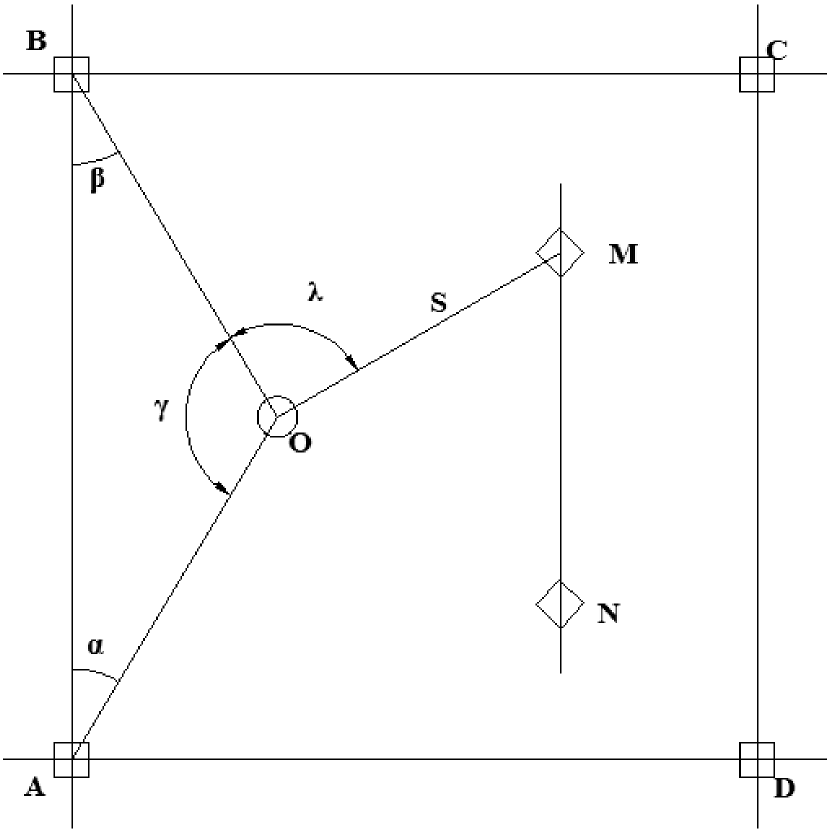
Purpose

Create the practical recommendations for building the geodesic marking construction base that will provide the accuracy and save geodesic work time on the construction site. These recommendations will allow to refuse from building the classic construction netting and conduct planning works with a GNSS receiver by using RTN methods [Shuljc, Medvedsjkyj, Mullenix et al., 2011; Parkinson, Spilker, 2006] and modern electronic total stations (ET).

Methodology

To build the graticule on the construction site, let's mark two basis AB and CD in-situ with the GNSS receiver, so they are parallel to the x and y axes of the general plan on which the site is projected. Then, let's mark the axes, using the method from the basic line as described in the work [Burak, 2011] (ET). To solve the problem, one has to know only the coordinates x and y of one basis point and set the position angle of the line to 0° or 90°. Theoretically all planning works may be done from one base line, but we recommend to set at least two in order to provide the visibility on the entire site including the possibility of losing important points during the construction work.

During planning and marking work, GNSS measurements on the nearest observation points are made a short distance from each other (not more than 1000 m), so the points will be located in ionospheric conditions and there will be a chance to see the same satellites. It allows to confirm, that influence of errors, entailed by ionospheric delays and satellite clock wrong time will be significantly decreased because of the compensation of their systematic component, that will improve the accuracy of set base lines. The information mentioned above was proven by our research. According to research results [Burak, Lysko, no. 27, 2017], when following the recommendations (adequate amount of measurement averaging, distance to the closest permanent stations, and geometry of their allocation [Burak, Lysko, no. 85, 2017]), it is possible to get the accurate mutual location 3, 18 mm (including the error of line orientation), and the accuracy of setting vectors – 2.52 mm on the distances less than 200 m [Burak, Lysko, no. 27, 2017]. It is important to remember that points A, B, C, D are set without such errors as device and viewfinder centering, as well as error of benchmark data. See Fig. 1.



◇ – *Geodetic network points*

○ – *Points of main axes fixing*

□ – *Location of ET*

Fig. 1. Typical diagram of planning works with RTN method

It is known that the measurement toward the baseline is based on measuring the distances l_1, l_2 and angle γ. It defines the coordinates of location after the ET and gives the opportunity to make amendments to the prototype without errors. Such a method has several advantages. For example, it is relatively simple in usage, the mutual accuracy of setting elements isn`t influenced by the errors of device centering, errors of point O fixing, and errors of benchmark data. However, it has the drawbacks as well, one of which is the absence of control. That's why it's recommended to repeat the measurements from both points O [Burak, 2011].

In case the points setting is made by a GNSS receiver and the base length is known, there is an opportunity to add one more additional control of defining the coordinates of point O. Let's review it in more detail. First, we have to set the length of the baseline, for example AB according to the cosine theorem.

$$\mathrm{AB} = \sqrt{l_1^2 + l_2^2 - 2l_1l_2\cos\gamma}. \qquad (1)$$

Then compare this value to the baseline length, defined from the coordinates of the equation.

$$\mathrm{AB} = \sqrt[2]{(X_b - X_a)^2 + (Y_b - Y_a)^2} \qquad (2)$$

where X_a, X_b, Y_a, Y_b – coordinates of fixing points obtained from the results of satellite observations.

Let's define the possible difference between these two values, estimated by the formulas (1) and (2). In order to simplify the process, let's review the case when the sides l_1 and l_2 are the same and are measured with ET with the same accuracy. Mean squared error (MSE) are equal m_{l_1}=m_{l_2}.

$$AB = \sqrt{2l^2 - 2l^2\cos\gamma} = \sqrt{2l^2(1-\cos\gamma)} \quad (3)$$

Let`s differentiate this function (3) on $\boldsymbol{l}$ and $\boldsymbol{\gamma}$ and receive:

$$\frac{\partial AB}{\partial l} = \frac{2l(1-\cos\gamma)}{\sqrt{2l^2(1-\cos\gamma)}} = \sqrt{2(1-\cos\gamma)} =$$

$$= \sqrt{\frac{4(1-\cos\gamma)}{2}} = \sqrt{4sin^2\frac{\gamma}{2}} = 2\sin\frac{\gamma}{2} \quad (4)$$

$$\frac{\partial AB}{\partial\gamma} = \frac{l\sin\gamma}{\sqrt{2(1-\cos\gamma)}} = \frac{l\sin\gamma}{\sqrt{4\sin^2\frac{\gamma}{2}}} = \frac{l\sin\gamma}{2\sin\frac{\gamma}{2}} =$$

$$= \frac{2l\sin\frac{\gamma}{2}\cos\frac{\gamma}{2}}{2\sin\frac{\gamma}{2}} = l\cos\frac{\gamma}{2} \quad (5)$$

From here:

$$m_{AB}^2 = \left(\frac{dAB}{dl}\right)^2 m_S^2 + \left(\frac{dAB}{d\gamma}\right)^2 \frac{m_\beta^2}{\rho^2} = =$$

$$= \left(2\sin\frac{\gamma}{2}\right)^2 m_S^2 + \left(l\cos\frac{\gamma}{2}\right)^2 \frac{m_\beta^2}{\rho^2}$$

$$m_{AB}^2 = 4m_S^2\sin^2\frac{\gamma}{2} + \frac{m_\beta^2}{\rho^2} l^2\cos^2\frac{\gamma}{2} \quad (6)$$

The maximum value will be:

$$m_{AB}^2 = 4m_S^2 + l^2\frac{m_\beta^2}{\rho^2} \quad (7)$$

Values by the formula (6) are illustrated in Fig. 2. The distance $\boldsymbol{l}$ is marked on the axis of abscissas and angle $\boldsymbol{\gamma}$ – on the axis of ordinate.

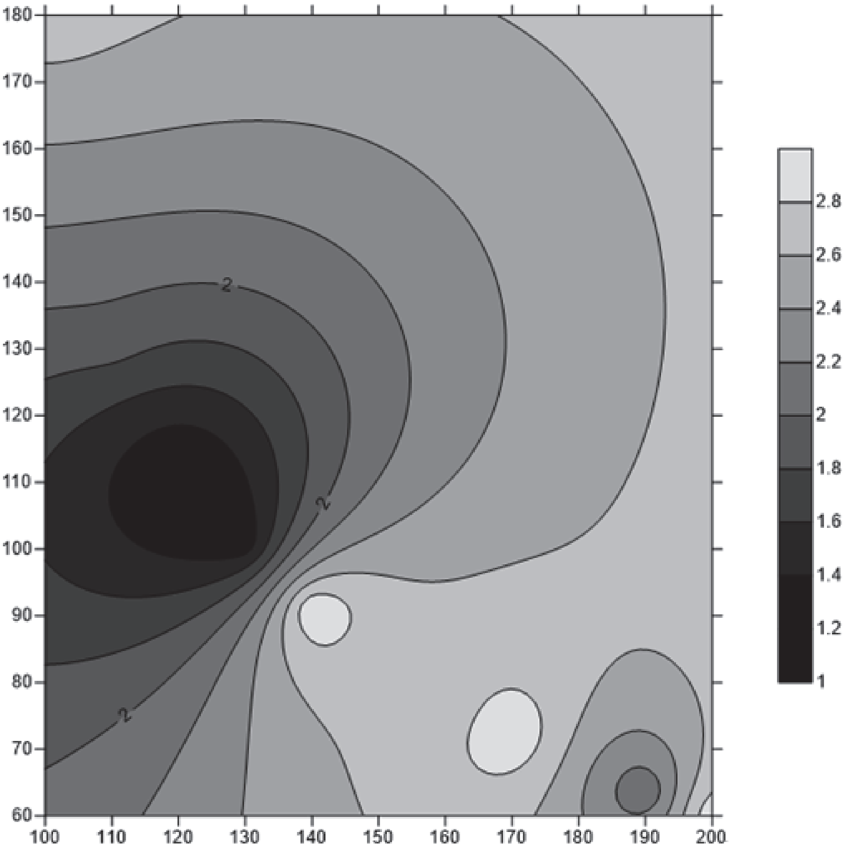


Fig. 2. Value of distance definition error depending on the location of point O on the construction site

Analysis shows that depending on the location of point A toward the baseline AB, the maximum and minimum m_{AB} values are $m_{AB\min}$ = 1.2 mm when l = 120 m, and m_{ABmax} = 3.0 mm, l = 140 m. The accuracy of defining the m distances m_S = 0.0015 m and angle m_β = 2″ were taken into account.

As it is known, the accuracy of the coordinate's definition by RTN method range from 2 to 5 cm depending on the mutual location of permanent stations and atmospheric conditions [Burak, Lysko, no. 27, 2017]. However, the previous works [Burak, Lysko, no. 85, 2017] defined that the relative accuracy of defining vectors with a GNSS receiver is always higher than from the accuracy of separate points due to the compensation of systematic error components, entailed by the atmospheric and ionospheric delays and errors of receiver and satellite clock.

If you follow the recommendations provided in the work [Burak, Lysko, no. 85, 2017], you will get the mutual accuracy of setting the vectors (lines) – 2,52 ± 0,01mm. In such a way, RMS of setting the basis AB by the satellite method and the maximum error of defining this distance toward the baseline will be equally accurate. It gives the opportunity to compare the data of distance value and additional control when measuring.

Consequently, when setting the basis by the dual-frequency GNSS receiver and the following marking of all the elements of construction site ET, it is possible to receive the accurate relative positioning of the sites from the single measurements even less than 2–3 mm and decrease the expenditure of time for geodesic works on the construction site.

Summary

According to the results of the research, it was established that when setting the fixing baseline with the dual-frequency GNSS receiver in the way its points coincide with the main axes of construction netting and the following marking of all the elements of the construction site toward this baseline, the required accuracy is provided, e.g. mutual location of points of main, basic, and detailed axes, and in some cases fitting axes as well. This method allows to abandon the creation of the common construction netting and reliably control the taken measurements.

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МОЖЛИВОСТІ ВИКОРИСТАННЯ RTN-РІШЕНЬ ДЛЯ РОЗМІЧУВАЛЬНИХ РОБІТ НА БУДІВНИЦТВІ

Мета дослідження. Розроблення практичних рекомендацій створення геодезичної розмічувальної основи будівництва з використання GNSS-технологій, зокрема RTN-методики. **Методика.** Для дослідження точності пропонованих рішень виконані дослідження, зокрема експериментальні в умовах будівельного майданчика, з розмічування осей від двох базових ліній, попередньо винесених GNSS-приймачем так, щоб вони збігалися з осями $\boldsymbol{x}$ і $\boldsymbol{y}$ генерального плану об'єкта. **Наукова новизна та практична значущість.** У роботі запропоновано замість суцільної будівельної сітки виносити тільки її основні осі, а від них безпосередньо за допомогою TPS (Total Positioning Station) розвивати розмічувальні мережі майданчика і споруди. Метод дає можливість відмовитись від побудови класичної будівельної сітки, замінивши опорну геодезичну мережу двома базовими лініями (мінімум 4 опорні точки), які закріплюють положення осей координат генерального плану та додатково контролювати розмічування осей TPS-способом від базової лінії, використовуючи для контролю значення віддалей між точками базових ліній, виміряне методом RTN.

Ключові слова: GNSS; TPS; RTN-вимір; розпланувальні роботи; електронний тахеометр.

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