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Use of Satellite Positioning Technology Using Reference Stations to Create Large-Scale Topographic Plans for Quarries

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***Abstract* – The use of technology of permanent (reference) base stations in surveying and geodetic works is a general trend in the developed countries of the world. This technology allows you to perform measurements with high accuracy in various areas of production. At present, the use of satellite technology in geodesy is limited at quarries in Vietnam and is mainly used to create a control network in the "Static" observation mode. The use of satellite positioning technology using reference stations allows you to simplify and improve the efficiency of geodetic surveys in quarries. However, Vietnam currently does not have its own network of base stations. This article presents the possibility of using a foreign network of base stations to create a topographic plan for the Nuubeo quarry (Vietnam).**

Keywords – GNSS; topographic survey; reference station; accuracy assessment.

I. INTRODUCTION

A permanent satellite base station (eng. Continuously Operating Reference Station) is a fixed GNSS receiver station that continuously receives satellite signals. Base stations combined with servers and the Internet data transfer system are a single network [1-5]. Such stations have a few advantages: the use of topographic and geodetic production in various areas, a wider coverage area, greater accuracy than traditional methods of measuring GNSS. It allows you to ensure long-term use, provide all users with a single reference coordinate system, standardize the database, improve the quality and performance of field data. The network of base stations allows real-time geodetic work in national or local coordinate systems, passing the corrections to the user on the rover.

Measurements using the network of base stations can replace the classic geodetic networks of all classes, to ensure accuracy requirements up to centimeters, millimeters. Therefore, it can be said that the creation of GNSS base station networks is a general trend in the world [12,14]. In the near future, this technology is planned to be created in Vietnam for coordinate support of geodesy and cartography in general and in mining areas in particular.

However, the current economic situation does not allow Vietnam to establish a network of GNSS base stations. Satellite positioning technologies using a foreign network of reference stations is an economical solution that meets technical requirements, standardizes the geodatabase, improves the quality and efficiency of field data.

II. METHODS AND MATERIALS

Currently, many countries around the world have created for themselves their own national network of GNSS base stations, working with various technologies suitable for the infrastructure and the use of each country [13,15]. Based on various methods of mathematical transformations and methods of organizing data transmission to the consumer, the existing network of base stations can be divided into several types [8-11].

Virtual base station ы (VRS) (Fig. 1) is intended to provide ameliorated mobile receiver (rover) operating in real-time kinematics (RTK) mode [5]. For its operation it is necessary that the coordinates of its approximate location be transmitted from the mobile satellite receiver to the control center. After receiving the rover location data, the network control center software based on the nearest base station creates differential corrections for the user relative to the virtual point in space (the so-called virtual base station) close to the location of the mobile satellite receiver at a given time, and transmits it to the user. Thus, each mobile satellite receiver receives individual corrections specially created for it, using which, the exact coordinates of its location are calculated in the same way as when determining the coordinates from a single base station.

The VRS technique makes it possible to model the errors of the ionosphere, troposphere and satellite orbits; two-way data transfer; simplified monitoring and control of mobile satellite receivers; high data transfer ability.

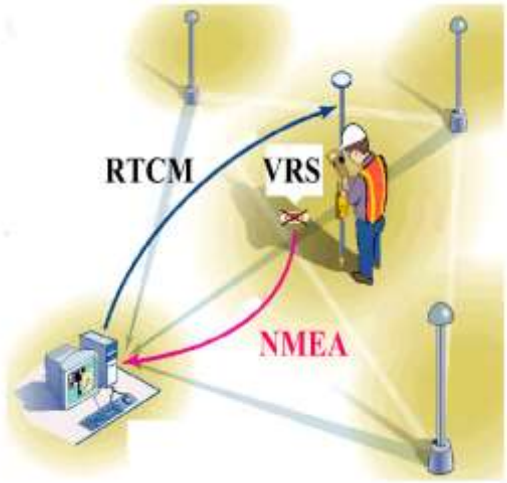


Fig.1. Virtual Base Station Method (VRS) [5]

Area correction method FKP (Flächen-Korrektur-Parameter) (Fig.2) was developed by Geo ++ [7]. This method uses base station information to obtain linear parameters that describe orbit and atmosphere influence errors. These parameters are transmitted to the control center to interpolate errors corresponding to different regions. The FKP technique has several advantages, such as one-way data transfer and high security, since the user only receives information without transferring it, as for example using the VRS method.

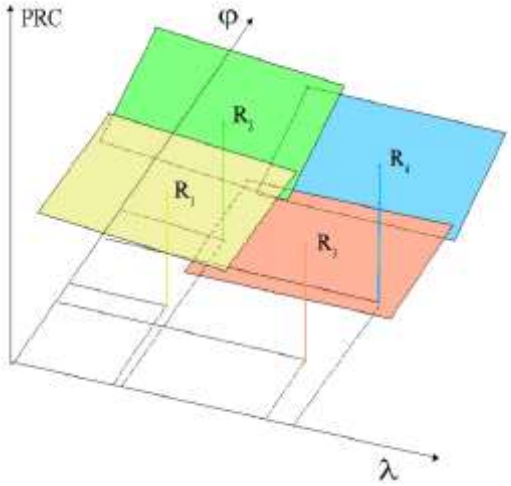


Fig. 2. Areal correction method FKP [7]

Method iMAC (iMAC - Individual Master-Auxiliary Corrections) (Fig. 3) was developed by Leica and Geo ++ [6]. The iMAC method works according to the following principle: the control center transmits the measured value of the master station (similarly to the RTK station), while at the same time, via the RTCM 3.1 protocol, transmits information about the difference between the secondary station and the master station. The mobile station, after receiving the information, begins to calculate its position corrections, and then accurately determines its location.

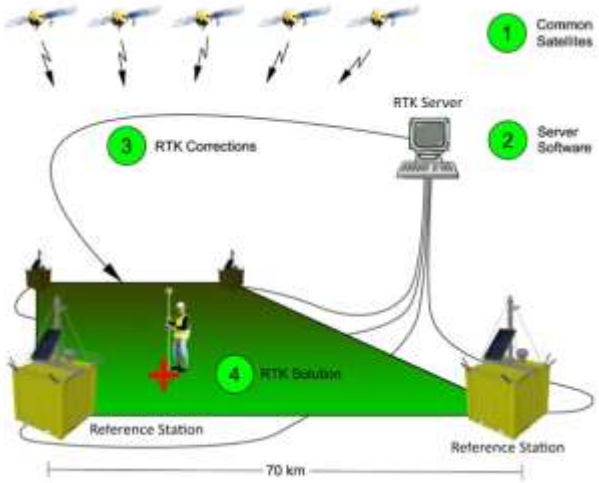


Fig. 3. Method iMAC [6]

Network Base Station Method (NRS – Net Reference Station). The NRS system works similarly to the virtual base station (VRS) method, also combines the advantages of the FKP and iMAC methods, forming a triangulation network using one or several nearest base stations to ensure the stability and quality of the transmitted data. NRS operates according to the DEEP-NRS method, when the minimum number of base stations created is three. Thus, the NRS system will meet the conditions of classical satellite networks, increasing the coverage of the triangulation network in the area based on the distances of the standard sides of the triangulation, selecting the best configuration from the base station sites to provide a mobile receiver.

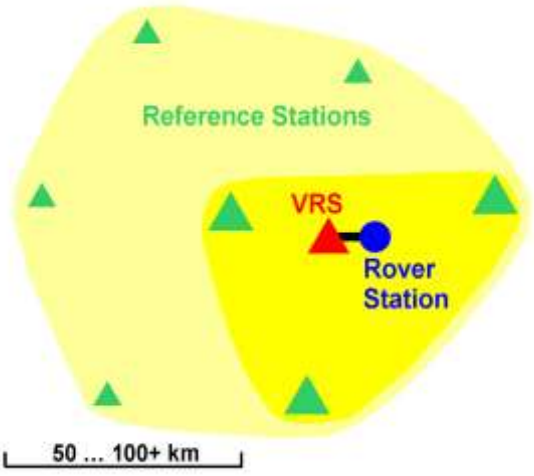


Fig. 4. Network base station system NRS [4]

In Vietnam, some independent base stations were built that are not yet interconnected, therefore the GNSS / PDBS / RTK measurement method is not widely used.

The method of measuring GNSS / PDBS / RTK using a foreign base station network is similar to the conventional GNSS / PDBS / RTK method, but a number of infrastructure requirements and some other necessary elements need to be met, such as:

– IP Address: Users must rent or buy the IP address of the network of base stations in another country. The network of base stations requires synchronization with the GNSS receiving equipment when in use. Currently, several base station networks lease and sell IP addresses worldwide for several hundred dollars, and some vendors provide IP addresses along with the purchase of equipment by the user.

– Telecommunication Infrastructure (3G): As a rule, GNSS receivers are connected to the network of base stations via the 3G network, therefore, to deploy PDBS technology, a good 3G / 4G telecommunication infrastructure is required, covering the entire measured area.

– Equipment: The GNSS receiver must be able to connect to base stations and to a 3G / 4G network. In addition, the GNSS receiver technology must be synchronized with PDBS network technology, which provide IP addresses to users.

TABLE I. COMPARISON OF GNSS MEASUREMENT METHODS

Method of measurement RTK	**The usual method of measuring GNSS / PDBS /RTK**	**The method of measuring GNSS / PDBS / RTK using foreign network PDBS**
Receiving GNSS signals	Receiving GNSS signals	Receiving GNSS signals
Requires 1 base and at least 1 rover	Only 1 rover required	Requires 1 base and at least 1 rover
-	Reception of correction signals from the local network of PDBs located in the measurement area	Reception of correction signals from the foreign network PDBS for the rover and the base
Distance from base to rover ≤ 10 km	The distance from the rover to the network PDBS ≤ 35 ÷ 40 km	The distance from the base to the rover depends on the signal of the 3G network The distance from the DPS network to the measured area is not limited.
The accuracy of determining the position on the plane is a few centimeters.	Accuracy of determining the position on the plane to centimeter	Accuracy of determining the position on the plane to centimeter
Accuracy in determining height less than 10 cm	Accuracy in determining the height is a few centimeters	Accuracy in determining the height to centimeter
-	The network of PDBS should be built in the measuring area	There is no need to build a network of PDBS
-	Available IP-address network PDBS	It is necessary to rent or buy the IP address of the foreign network of PDBS

There are differences between the GNSS / PDBS / RTK measurement method using a foreign base station network and the conventional GNSS / PDBS / RTK method. For the conventional GNSS / PDBS / RTK method, at least one GNSS receiver connected to the PDBS network with coverage per work area can be used. The GNSS / PDBS / RTK measurement method using a foreign base station network requires at least two receivers. In this case, the first receiver is stationary (base), which is located on an open area in the absence of radio interference. The base must support connection to mobile receivers via several channels, so that they can link and receive correction data from the PDBS network. Typically, the base allows you to create a connection from 1 to 22 different channels, and the rovers take one communication channel and connect to the base.

The GNSS / PDBS / RTK measurement method using a foreign base station network showed some advantages over the traditional RTK method and the method connected to the local base station network (see Table 1)

III. RESULTS

In order to assess the accuracy of the GNSS / PDBS / RTK measurement method using the foreign PDBS network at a quarry in Vietnam, a number of measurements were made on various benches with marks from + 35 to –100 m at the coal-mining site No. 14 of the Nuybeo quarry (Vietnam). The coordinates of the pickets were determined twice: using the GNSS / PDBS / RTK method and an electronic total station. The points located along the edges of the pit ledges at various levels were selected as control pickets.

The study used satellite receivers Kolida Kolida K9-T. They are connected to a foreign base station network by IP address 117.129.03.123. These GNSS receivers and base station networks operate in accordance with the NRS correction method. The signal quality of the 3G network in the area is rather unstable, since BTS stations were installed in the quarry area to improve the quality of the telecommunications signal. The total station used was a Leica TS06. Before the measurements were checking and adjustment of the total station. The difference in coordinates of points measured by two methods is determined by the following formula:

$$d_x = X_c - X_{td},\ d_y = Y_c - Y_{td},\ d_z = Z_c - Z_{td} \quad (1)$$

where: d_x, d_y, d_z – position errors of a point along the X axis; Y and height error.

Error positioning points on a plane:

$$m_p = \sqrt{dx^2 + dy^2} \quad (2)$$

The results of the comparison are shown in table 2.

TABLE III. COMPARISON OF TWO MEASUREMENT METHODS

No. control picket	d_x, *м*	d_y, *м*	d_z, *м*	m_p, *м*
1	-0.026	-0.019	-0.006	0.032
2	-0.027	-0.004	0.005	0.027
3	0.015	-0.005	-0.005	0.016
4	-0.008	0.001	-0.015	0.008
5	**-0.049**	**0.003**	**-0.017**	**0.049**
6	**-0.107**	**-0.006**	**-0.015**	**0.107**
7	-0.022	-0.011	-0.008	0.025
8	0.009	-0.018	0.005	0.020

After assessing the accuracy of the pickets based on the results of two measurement methods, a topographical survey at the coal open-pit mine was taken using the GNSS / PDBS / RTK method using a foreign base station network. Surveying was carried out on ledges with marks from +0 to -90 m. The data obtained using the TOPO software interpolated the contour lines (see Fig. 5). A comparison of the results of interpolation by points coordinated by different methods shows that the two fragments of the topographic plan are almost identical.

In table 2, pickets 5 and 6 have significant errors. This may be due to the delay of the 3G signal from the satellite to two receivers, poor direct visibility between GNSS satellites and receivers, etc. However, these errors appear only in the minimum number of pickets.

The reason for the discrepancy between the two topographic plans established by two methods - the GNSS / PDBS / RTK method using a foreign base station network and the method using a total station is associated with the difference in the location of the measured points to describe the career levels in the two methods. However, the difference between the two methods at each career level is not significant.

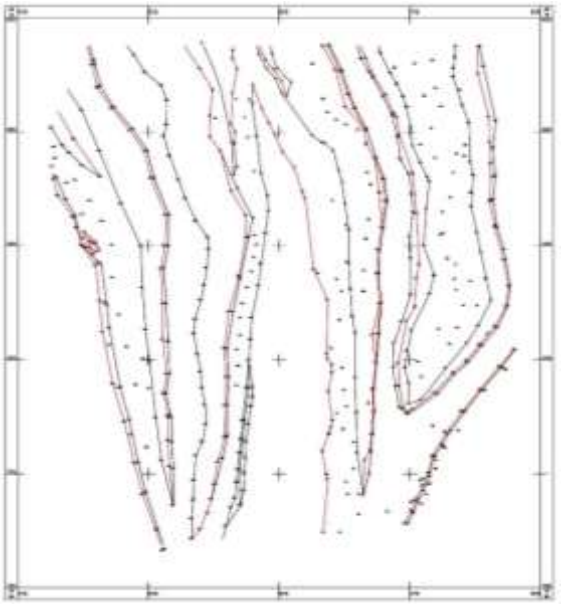
IV. CONCLUSION

In modern conditions in Vietnam, the GNSS / PDBS / RTK measurement method using a foreign base station network is an effective solution for increasing productivity, quality and cost-effectiveness.

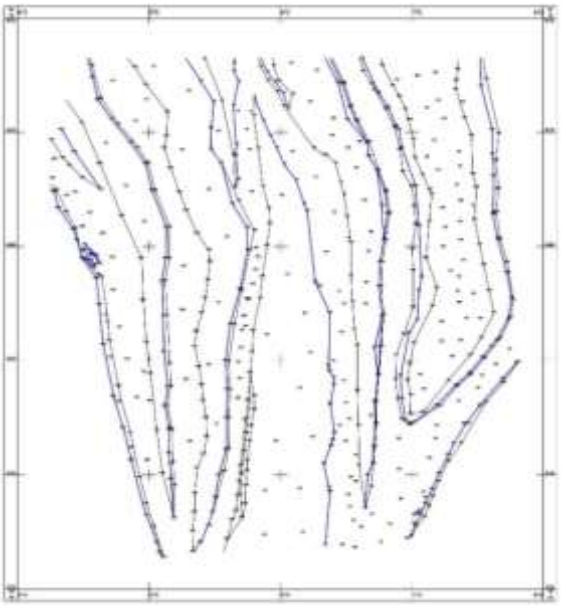
The GNSS / PDBS / RTK measurement method using a foreign base station network ensures accuracy when creating maps in general and career maps, the scale of which is 1: 1000 or less.

In the area of the quarry, many BTS stations were installed to improve the quality of the telecommunications signal. It is a good infrastructure platform that meets the requirements of the GNSS / PDBS / RTK measurement method using a foreign base station network.

The GNSS / PDBS / RTK measurement technology using a foreign base station network is used in many countries of the world. It has advantages over other positioning methods. The creation of a network of base stations in Vietnam covering the entire territory of the country will make it possible to solve more quickly, without compromising accuracy, several applied geodesic tasks.



a) Horizontal obtained at characteristic points coordinated by the total station



b) By the method of GNSS / PDBS / RTK

Fig. 5. Topographic plan of the study area, the levels of which are from +30 to -60 m.

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