Smart Geotechnics for Smart Societies – Zhussupbekov, Sarsembayeva & Kaliakin (Eds)

Developing a methodology to improve GNSS monitoring of dynamic objects

Zh.M. Aukazhiyeva, S.S. Sattarov, A.M Muratova & A.S. Sariyeva
L.N. Gumilyov Eurasian National University, Astana, Kazakhstan

ABSTRACT: The issues and examples of remote monitoring, methods of technological improvement on the example of bridge structures are considered. After the analysis of the problems and examples of deformation monitoring was carried out, the next stage of the development of a technique for technological improvement began. As the analysis showed, the big problem of GNSS is the distortion of the signal from satellites. Also, international experience has shown under what conditions it is possible to use satellite coordinate determination. The first step in developing the methodology will be to study the conditions of monitoring and the object of research itself. And only then, starting from the specifics of the bridge structure, the optimal options for the provision of deformation monitoring with the use of satellite technologies will be considered.

1 LOCATION OF DEFORMATION MONITORING

The arch-cable-stayed bridge “Arkhar” is located in the center of the capital Astana and passes through the Ishim River. This object is one of several bridges connecting the left and right banks of the city. A four-lane highway runs along the bridge in two directions. Pedestrian paths are also laid along the edges. Figure 1 shows the bridge “Argali” [1].

Figure 1. “Argali” bridge in Astana.

DOI: 10.1201/9781003299127-329

The basis of the bridge design is two arches running along the bridge. Arches hold the roadbed with the help of a system of cables. This bridge is the first cable-stayed bridge built in the capital.

The width of the bridge is 40 meters with a length of the central part of 150 meters. During the development of the project, it was decided that the bridge would have an arched superstructure with a special configuration. According to the architects' plan, all connected structures and struts passing over the roadway were removed. This decision was made for the sake of a special architectural style. Therefore, special arches were designed for stability, located along the sidewalks on each side. One arched element consists of two interconnected flexible arches. The roadbed was supported by a cable-stayed system developed by the French company Freyssinet. This solution gave the lightness of the design and a positive perception from the point of view of architectural aesthetics. In fact, the bridge structure consists of two parallel arch bridges connected by a roadway with a beam cage.

Today, the bridge "Argali" is one of the main ways to cross the Ishim River. Every day, a relatively large flow of cars passes over the bridge. This is especially noticeable on weekdays, between 8:00-10:00 in the morning and in the evening at 19:00-21:00. These time intervals are considered rush hour, as many residents of the capital go to and from work. Consequently, in the morning and evening there will be fluctuations in the bridge due to the load of the traffic flow.

With regard to weather conditions, a sharply continental climate prevails in the capital. In summer, the temperature can reach up to +35 degrees Celsius. Solar activity exerts uneven heating on the bridge structure, resulting in deformation processes. It is also worth noting that Astana is located on a flat terrain. Therefore, a strong gusty wind is a normal phenomenon both in winter and in summer. The wind load causes fluctuations in the bridge structure. Such fluctuations are noticeable when walking across the bridge [2].

Having studied the features of the Argali Bridge and familiarized ourselves with the climatic conditions, we can begin to develop a methodology for technological improvement. During the development process, we will consider the above sources of error in GNSS surveys, and study ways to correct them. As a result, an up-to-date methodology for conducting deformation monitoring using GNSS technology for the Argali bridge is expected. As mentioned earlier, each object is a unique object, and in developing the methodology it is worth remembering this and starting from the real situation at the object.

Turning directly to the development, it is worth noting that satellite technologies represent a relatively new direction in geodesy. Satellite positioning technologies are becoming more advanced every year. And at the moment, the maximum accuracy of determining the coordinates of a point has reached a sub-centimeter indicator. Achieving such accuracy largely depends on the equipment used, since modern geodetic equipment is able to level the influence of errors to a minimum.

During the analysis of the problems of improving the GNSS monitoring methodology, it was decided to divide the workflow into two stages. The first stage is the technological improvement of field survey using GNSS. At this stage, possible improvements in point-by-point shooting will be considered. The second stage is the technological improvement of in–house processing with the use of up-to-date software. In the improvement plan, special attention will be paid to optimizing the processing of geodetic measurements, their further integration with GIS and final visualization.

2 IMPROVEMENT OF THE FIELD SURVEY METHODOLOGY

Technological improvement of the field GNSS survey technique consists in the selection of the optimal way to eliminate errors. To do this, let's go through each type of errors that occur during the geodetic survey. Figure 2 lists the main types of errors during GNSS shooting [3].

The main sources of satellite measurement errors are:

- desynchronization of satellite onboard clocks, ephemeris errors, unsuccessful geometric arrangement of satellites in the sky;
- errors resulting from signal delay when passing through the troposphere and ionosphere;
- errors related to the receiver (noise, signal re-reflection, etc.).

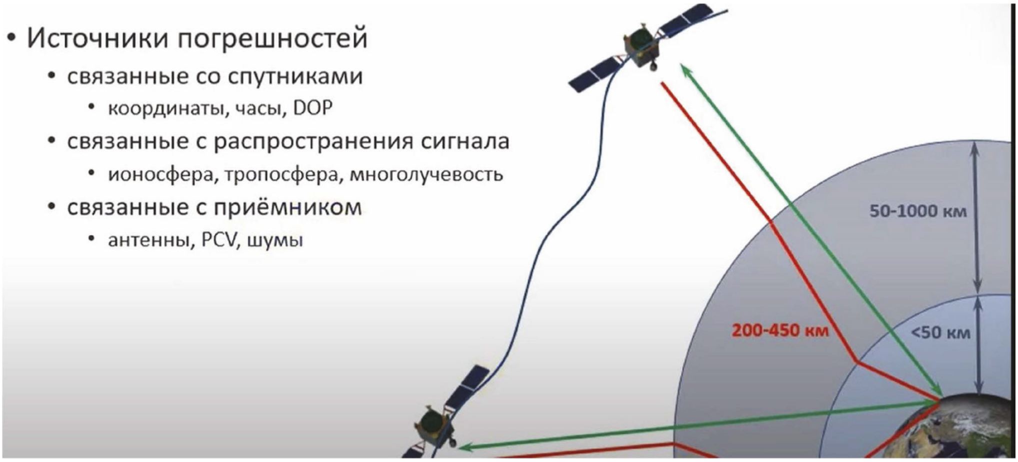

Figure 2. Sources of errors in GNSS shooting.

Let's start with the errors associated with the satellite segment. Ephemeris errors can be eliminated by updating the ephemeris database. Depending on the GNSS equipment used, the selection of current databases is made. Ephemeris data is available on the official websites of GPS, GLONASS, etc. Errors caused by the discrepancy between the clocks of the satellites and the receiver are leveled by calibrating the receiver. Therefore, when using geodetic equipment, it is always necessary to carry out alignment, after which several test measurements should be made at reference points. The error associated with the DOP (dilution of precision) indicator is eliminated by selecting the optimal shooting time. The DOP indicator itself means a concept used in the field of global positioning systems for parametric description of the geometric relative position of satellites relative to the receiver antenna. Figure 3 shows two examples of the location of satellites, where the first option is unsuccessful, since the close location of the satellites and a small angle give an incorrect result. Also, to work with GNSS, it is necessary that at least four satellites are available [4].

Next, in Table 1, we will look at the DOP values, which show us how optimal the spatial location of the satellites is. DOP indicators range from 1 to 50, where 1 is the best value.

Next, we will analyze the errors associated with the GNSS receiver. One of the common mistakes associated with the receiver antenna is the incorrect determination of the antenna phase center. Before installing the receiver in the operating state, it is necessary to determine the location of the phase center. This is usually done in the monitoring project setup menu. By default, the phase center of the antenna is located at the base of the receiver attachment to the vertex [5]. It is recommended to use this option, since when centering above the point, it will be easier to maintain the level of the axis relative to the plane of the device's standing. Also, the appearance of noise during the transmission of a radio signal is inevitable. But this error can be eliminated at the stage of desk work, since such measurements stand out strongly against the background of other correct ones. If the signal quality is poor, an additional antenna can be used [6].

Most of the listed errors can be compensated with the relative method of determining coordinates. Also, modern GNSS receivers coupled with controllers are able to eliminate the impact of gross errors. Most modern receivers operate at several frequencies at once, which helps to avoid the influence of signal delay through the ionosphere.

One of the most dangerous errors is the re-reflection of the signal, since the error greatly affects the accuracy. Multipath occurs as a rule in urban areas where there are many high-rise buildings. This problem is solved by correctly positioning the points in an open space. In our case, on the Argali Bridge, large distortions will occur under arched structures that overlap the horizon and the sky.

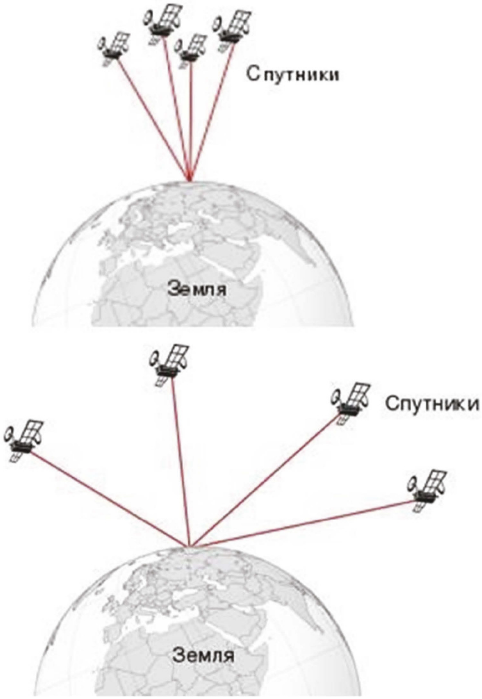

Figure 3. Variations of the spatial location of satellites in the sky.

Table 1. DOP values.

DOP values	Accuracy	Description
1	Ideal	The best indicator, recommended for work requiring maximum accuracy
2-3	Excellent	Sufficient accuracy when working with sensitive equipment
4-6	Good	The minimum allowable value for measurements used in production
7-8	Average	Acceptable results for navigation, it is recommended to try to go to a more open space to improve accuracy
9-20	Below average	The results can be used to determine the approximate location
21-50	Bad	The accuracy of determining the position is equal to half of the football field, the results are subject to rejection

Now let's move on to choosing the shooting mode. In previous chapters, we discussed the advantages of relative methods of satellite observations, namely the static mode. In static mode, the receiver stands still. But since we have the ability to connect the base station, the measurements will be carried out in RTK mode. This method is most suitable for deformation monitoring. After the rover is installed at the facility, we will use a SIM card to connect to the Geokurs base station, located not far within a radius of 5 km from the Arkhar Bridge. As a result, we will succeed, so that our rover in RTK shooting mode will calculate its location for a certain time. The resulting calculations will already go together with the differential corrections and with the postprocessing performed. The expected measurement accuracy should be a few centimeters. After completing the shooting at one station, we will move on to the next. In total, it is planned to make 6 observation stations. This amount will be enough for our research object. As a result, we expect to receive spatial data that displays up-to-date information about the vibrations of the bridge. At the experimental stage, we will determine the method of station placement and the choice of equipment used [7].

REFERENCES

1. Measurements of long lengths, coordinate-time and navigation measurements. Research and development and operation of metrological support of coordinate-time and navigation systems [Electronic resource]. URL: http://www.vniiftri.ru/index.php/ru/struct/nio-8 (accessed 25. 04. 2015).
2. Kalabin E. V., Lokhov V. S. Principles of conducting continuous monitoring on geodynamic objects // Geoprofi. 2012. No. 2. pp. 58–61.
3. Kaftan V. I., Dokukin P. A. Determination of displacements and deformations according to satellite geodetic measurements // Geodesy and cartography. 2007. No.9. pp. 18–22.
4. Kuzmin Yu. O. Modern geodynamics of fault zones: faulting in real time // Geodynamics and tectonophysics. 2014. No. 2. pp. 401–443.
5. Lapshin A. Yu., Staroverov S. V., Fyalkovsky A. L. Investigation of the daily movement of the Shukhov Tower by satellite methods/Ninth All-Russian Conference: “Prospects for the development of engineering surveys in construction in the Russian Federation”: collection of materials. 2013. p. 127130.
6. Leggett R. Cities and geology. Moscow: Mir, 1976. 560 p.
7. Lobazov V. Ya., Mayorov A. A., Yambaev H. K. Geodynamic monitoring of architectural monuments of the Moscow Kremlin // Izv. vuzov “Geodesy and aerial photography”. 2009. No. 3. pp. 3–12.