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«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
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«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ» РҚБ

Х А Б А Р Л А Р Ы

ИЗВЕСТИЯ

РОО «НАЦИОНАЛЬНОЙ
АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН»

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NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.

Қазақстан Республикасы Ұлттық ғылым академиясы «ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

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CREATION OF GEODETIC REFERENCE NETWORK FOR MONITORING TRANSPORT INTERCHANGES IN SEISMIC AREAS

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Abstract. Article presents information on creation of the reference geodetic network for organization of geodetic monitoring of a long bridge, in particular the Momyshuly Street — Raimbek Avenue interchange in Almaty, Republic of Kazakhstan. Almaty is located in a high seismic activity region. Issue of using satellite positioning technology to create reference geodetic network is considered. Overview of both classical methods of geodetic observations and modern devices and technologies used to determine quantitative characteristics of bridge deformations is given. Original technology of direct satellite measurements with analysis of its accuracy is presented. *Results.* Methodology for creating reference network for monitoring bridge deformations has been developed. Research results have been implemented in the project "Development of innovative methods for forecasting and assessing the state of engineering structures to prevent technogenic emergencies" and have also been used in the educational process. *Scientific novelty*. As a result of research work, following have been created and implemented in production:

- diagram of reference geodetic network of bridge location area;

-developed reference geodetic point of forced centering (FCP), which allows increasing productivity and accuracy of observations;

Novelty of developed network and point design are confirmed by the Certificates of the Republic of Kazakhstan for work of science. *Practical value*. Results obtained can be used to improve level of industrial safety at other facilities and minimize risks caused by seismic activity in the area.

Keywords: bridge, deformations, monitoring, reference geodetic networks, satellite positioning, geodetic observations, accuracy assessment

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СЕЙСМИКАЛЫҚ АУДАНДАРДАҒЫ КӨЛІК АЙРЫҚТАРЫН МОНИТОРИНГТЕУ ҮШІН ГЕОДЕЗИЯЛЫҚ ТІРЕК ТОРАБЫН ҚҰРУ

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Аннотация. Мақалада Қазақстан Республикасы, Алматы қаласы Момышұлы көшесі - Райымбек даңғылы көлік айрығын қоса алғанда, қалааралық көпірдің геодезиялық мониторингін ұйымдастыру үшін геодезиялық тірек торабын құру туралы зерттеу жұмыстарының нәтижелері келтірілгенсынылды. Алматы сейсмикалық белсенділігі жоғары ауданда орналасқан. Геодезиялық тірек желісін құру үшін спутниктік позициялау технологиясын қолдану мәселесі қарастырылуда. Классикалық геодезиялық бақылау әдістеріне де, көпір деформацияларының сандық сипаттамаларын анықтау үшін қолданылатын заманауи аспаптар мен технологияларға шолу жасалады. Оның дәлдігін талдай отырып, тікелей спутниктік өлшеудің түпнұсқа

технологиясы ұсынылған. Нәтижелері. Көпірлердің деформацияларын бақылау үшін тірек торабын құру әдістемесі жасалды. Зерттеудің нәтижелері «Техногендік сипаттағы төтенше жағдайлардың алдын алу үшін инженерлік құрылыстардың жай-күйін болжау мен бағалаудың инновациялық әдістерін әзірлеу" жобасын орындау кезінде өндірісен енгізілді, сондай-ақ оқу процесінде пайдаланылды. Ғылыми жаңалығы. Жүргізілген ғылыми зерттеу жұмыстарының нәтижесіде:

- көпір орналасқан ауданның геодезиялық тірек торабы жасалынлы;
- бақылаулардың өнімділігі мен дәлдігін арттыруға мүмкіндік беретін мәжбүрлеп центрлеудің (ЖЦП) әзірленген геодезиялық тірек пункт әсірленді;

Әзірленген тірек торабы мен пункт конструкциясының жаңалығы ғылым туындысына ҚР куәліктерімен расталды. Практикалық құндылық. Алынған нәтижелер басқа нысандардағы өндірістік қауіпсіздік деңгейін арттыру және ауданның сейсмикасынан туындаған тәуекелдерді азайту үшін пайдаланылуы мүмкін.

Түйін сөздер: көпір, деформациялар, мониторинг, геодезиялық тірек торабы, спутниктік позициялау , геодезиялық бақылаулар, дәлдікті бағалау

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СОЗДАНИЕ ОПОРНОЙ ГЕОДЕЗИЧЕСКОЙ СЕТИ ДЛЯ МОНИТОРИНГА ТРАНСПОРТНЫХ РАЗВЯЗОК В СЕЙСМИЧЕСКИХ РАЙОНАХ

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Аннотация. В статье приведены сведения и результаты создания опорной геодезической сети для организации геодезического мониторинга моста большой протяженности, частности транспортной развязки улица Момышулы – проспект Раимбека в городе Алматы, Республика Казахстан. Алматы находится в повышенном сейсмическом активном регионе. Рассматривается вопрос о применении технологии спутникового позиционирования для создания опорной геодезической сети. Дан обзор как классических методов геодезических наблюдений, так и современных приборов и технологий, применяемых для определения количественных характеристик деформаций мостов. Приведена оригинальная технология непосредственных спутниковых измерений с анализом ее точности. Результаты. Разработана методика создания опорной сети для ведения мониторинга деформаций мостов. Результаты исследований внедрены при выполнении проекта «Разработка инновационных методов прогнозирования и оценки состояния инженерных сооружений для предупреждения чрезвычайных ситуаций техногенного характера», а также использованы в учебном процессе. Научная новизна. В результате проведенных научно-исследовательских работ созданы и внедрены в производство:

- схема опорной геодезической сети района расположения моста;

- разработанный опорный геодезический пункт принудительного центрирования (ППЦ), позволяющие повысить производительность и и точность наблюдений. Новизна разработанной сети и конструкции пункта подтверждены свидетельствами РК. Практическая ценность. Полученные результаты могут быть использованы для повышения уровня производственной безопасности на других объектах и минимизации рисков, вызванных сейсмикой района.

Ключевые слова: *мост, деформации, мониторинг, опорные геодезические сети,* спутниковое позиционирование, *геодезические наблюдения* , оценка точности

Introduction

In recent years, many transport interchanges have been built in Almaty, such as Saina -Monke bi, Seifullin-Zhandosov, Al-Farabi-Ryskulov, Momyshuly-Raimbek and others. Almaty is located in specific engineering and geological conditions and is in the zone of influence of strongest earthquakes of the Northern Tien Shan. In addition, city territory is crossed by tectonic faults in all directions. In these conditions, forecasting problem of technical condition of structures under construction and in operation becomes acute. Its solution is provided by geodetic monitoring. Intensive development of Almaty, expressed in changes in its layout, emergence of new large engineering structures, such as interchanges and long-distance bridges within the city limits, and borders expansion affect the size and load of geological faults. In this regard, seismic condition accounting of cities and urbanized areas represents practical interest.

Object of the study is the traffic interchange at the intersection of Baurzhan Momyshuly street and Raimbek Avenue. In geomorphological terms, site under study is located within the foothill sloping plain extending north from foothills of the Zailiyskiy Alatau (Fig. 1).

Geological structure. Geological and lithological structure of site includes alluvial-proluvial Upper Quaternary deposits. In lithological terms, they are represented by pebble soils covered by loess-like loams, rarely by sandy loams. To detail geological and lithological section, 51 boreholes, 10,0–18,0 m deep each, were drilled on the site. A total of 806,0 running meters were drilled, including 49,0 m by a borehole (on bulk soils).

Fig. 1 - Bridge along B. Momyshuly Street - Raimbek Avenue

Below, pebble gravels with sand filler up to 20–30 %, low-moisture, with inclusion of boulders up to 25–30 %, are exposed (in wells NN1; 4; 5; 7; 8; 11; 12 to a depth of 6.0–6.7 m, pebble soils with loamy filler). Exposed thickness of pebble gravel is 4,9–14,2 m. (Nusipov, 2001; Medeu et al., 2018).

In hydrogeological terms, construction site is located within regional depression funnel of the Alma-Ata water intake system. According to research of the KazGIIZ Institute, in the 1970s, groundwater in this area was at a depth of less than three meters, in 1990–92 at a depth of 6–10 m, in 2005–2006 groundwater level was about 4,5 m.

Seismic engineering conditions of construction site. Construction site of the Raimbek Ave. - Momysh Uly interchange is located in the zone of possible manifestation of the Almaty tectonic fault on daylight surface, which is confirmed by results of archive materials of the Kazakh Geotechnical Survey Institute (KazGII). In KazGII, according to preliminary developments and world data, when designing and constructing on requested site in fault zone, acceleration and displacement values should be increased by 20 %, i.e. taken with a coefficient of 1,2, in relation to similar seismic engineering conditions outside fault manifestation zone. According to Comprehensive Seismic Zoning Map of Almaty and Adjacent Territories, construction site of Raimbek Ave. - Momysh Uly interchange is located within boundaries of the Almaty seismic fault

Initial seismicity of area is 9 points. Category of soils according to seismic properties within construction site of the interchange is II (second). Updated value of site seismicity is 9 (nine) points (Erzhanov, 1982; Nurpeisova et al., 2019).

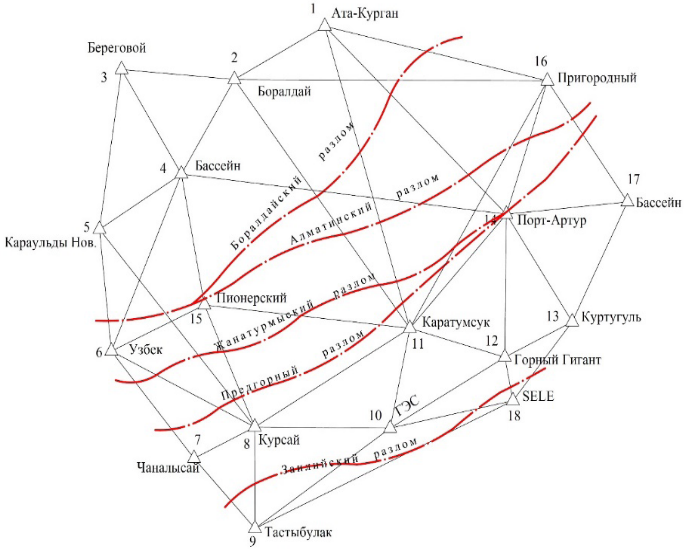

Figure 2 - Scheme of tectonic faults combined by triangulation points

Methodology. Work uses comprehensive approach, including: engineering-geological study of structural-tectonic structure of rock massif in area of bridge construction, changes assessment in the stress-strain state of massif using satellite geodesy technologies, instrumental geodetic observations using electronic tacheometer, area monitoring of interchange territory using ground scanning and UAVs (Nurpeisova et al., 2015).

Main content. Construction of interchanges, bridges, as well as construction of any other structures, requires creation of geodetic reference network. Using geodetic reference networks, centers position of bridge supports, and other bridge elements is determined and fixed, detailed breakdown is made during construction of supports and installation of span structures, and structures deformations are observed. Geodetic network during bridge construction must be created in single coordinate system and have increased accuracy in determining coordinates of points. Geodetic network points that ensure construction of given object as a single structure must exist during object construction. This requirement is not easy to fulfill, since during construction some of geodetic network points are destroyed or damaged.

Geodetic reference network is basis of entire spectrum of construction work. Its creation has always been carried out with special care and responsibility. In recent years, construction of geodetic reference network has become possible using GPS and GLONASS positioning technologies, etc. In technical literature, there are quite a few descriptions of its use for constructing special networks, especially for the needs of geodesy, but there are quite a few descriptions of its use in monitoring bridge deformation.

At the same time, main document «Instructions for the production of geodetic works» (Nurpeisova et al., 2019; Instructions, 02-262-02) emphasizes that geodetic reference networks can be created using satellite equipment. Moreover, it should be noted that their use is very effective and in some cases is the only possible option. Starting points for constructing geodetic reference network are points of the state geodetic network (SGN).

Satellite geodetic receivers are currently widely used in geodetic production. Their main purpose is high-precision determination of geocentric coordinate increments. During performing field measurements, receivers use radio signals from GPS satellite navigation systems. Use of satellite geodetic receivers for geodetic support of surveys, construction and operation of engineering structures ensures higher accuracy and greater productivity than traditionally used geodetic technologies. At present, satellite methods are quite widely used to create geodetic densification networks in built-up areas; in development of geodetic networks for planned support of large-scale topographic and cadastral surveys; in large-scale topographic surveys and in other types of geodetic work.

Since the advent of the GLONASS and GPS satellite navigation systems and based on continuous improvement of satellite measurement technology, problems of creating geodetic reference networks have been solved on qualitatively new basis. Development of highly effective satellite methods of coordinate determination based on use of global navigation systems fundamentally changes technology and accuracy of determining geodetic coordinates and principles of constructing geodetic networks. Based on results of satellite measurements, precise coordinate values are determined simultaneously both in plan and in height. Therefore, modern satellite methods of coordinate determination based on use of global navigation systems GPS and GLONASS establish conditions for creating plan and height basis in form of set of geodetic points.

Use of location determination methods based on signals from global navigation satellite systems GPS and GLONASS (GNSS) for engineering and geodetic works began at the end of the 20th century, but engineering and geodetic reference networks for construction of long bridges in mountainous areas are still insufficient. Thus, objective of this paper is to develop methodology for creating reference networks during construction of long bridges in seismic areas using satellite measurement methods, as well as scientific justification for chosen methodology and determination of path for its practical implementation. It is also necessary to develop algorithms for processing satellite data, transforming coordinates from the WGS-84 or PZ-90 coordinate system into local coordinate systems and assessing the accuracy of the calculated increments of Almaty coordinates.

Difficulty lies in fact that high accuracy of determining differences in the coordinates of points is accompanied by some errors. During performing high-precision work, it is necessary to consider not only curvature of the Earth, but also geodetic height of object under construction.

Therefore, to solve problem of effectively using modern satellite technologies to create backbone networks during construction of long-distance bridges in mountainous areas, it is necessary to perform:

- analysis of methods for creating planned support networks during construction of long-distance bridges in mountainous areas;
- analysis of ustification for accuracy characteristics required for support networks during construction of long-distance bridges in mountainous areas;
- analysis of features of processing satellite measurement results when creating reference networks;
- justification for choice of reference surface during construction of long-distance bridges in mountainous areas;
- method modernization for converting coordinates from WGS-84 or PZ-90 coordinate system to local coordinate system;

- assessment of accuracy of calculated coordinate increments in local coordinate systems;
- development of computer programs for converting coordinates obtained from satellite measurements into a local coordinate system.

One of the characteristic features of geodetic support for construction of long-distance bridges is combination of high measurement accuracy and significant extent of geodetic networks. During constructing bridges, as a rule, in remote, sparsely populated areas with poor topographic and geodetic support, satellite technologies are the most attractive in terms of efficiency of their use.

Modern satellite receivers provide high measurement accuracy: from few millimeters at short distances to several centimeters at distances of tens and even hundreds of kilometers. However, this accuracy refers to spatial rectangular coordinate systems (PZ-90 for the GLONASS system or WGS-84 for the NAVSTAR GPS system), which are practically impossible to use for most types of geodetic work (Roberts, 2003).

At the same time, it is impossible to make transition from a spatial rectangular coordinate system to coordinate systems adopted in geodesy without loss of accuracy. There is no single three-dimensional coordinate system in geodesy. There is only a curvilinear two-dimensional coordinate system (latitude B and longitude L on the surface of reference ellipsoid), or its analogue in coordinates of the Gauss-Kruger projection, which, in fact, is also a curvilinear coordinate system, where length of meridian arc is plotted along abscissa axis, and Ordinate axes use a limited zone of 3 or 6°, and distortions within the zone are considered acceptable. The third coordinate - normal height - has practically no connection with the Earth's center of mass, but is measured from its own surface of reference - the quasi-geoid.

The lack of information about exact value of height anomaly significantly complicates transition from rectangular coordinates to curvilinear ones and can introduce noticeable distortions into the coordinates. It should be noted that the height anomaly on the territory of Russia varies widely from -8 m in the Caspian lowland to 50 m in Vladivostok relative to the Krasovsky ellipsoid; this value ranges from -7 m to 10 m relative to the WGS-84 ellipsoid.

During creating a reference network using satellite measurement methods, it should be borne in mind that in construction area local coordinate system and local reference surface of measurement results are used, in accordance with heights in construction area.

In engineering and geodetic work, local coordinate system is often used. This is due to fact that coordinates of points of state geodetic networks are related to surface of reference ellipsoid, where geodetic height is zero, and it is necessary to build at heights significantly different from zero, especially in mountainous areas.

Requirements that must be observed when creating support networks during bridge construction are as follows:

1) normal conditions for performing high-quality measurements must be provided at the points;

2) it is necessary to ensure the safety and stability of network points for a long time;

3) it is necessary to ensure unhindered use of network points to carry out marking work;

4) network design must provide for required number of redundant measurements for purposes of monitoring field measurements and subsequent adjustment;

5) network diagram must ensure the determination of the coordinates of network points with the required accuracy;

6) network must be cost-effective.

All above conditions can be attributed to any of methods for creating geodetic alignment networks.

When constructing reference networks using satellite measurements, it is necessary to make maximum use of fact that accuracy of determining coordinate increments in the network practically does not depend on the geometry of network and, in addition, it is not necessary to ensure visibility between adjacent points if this is not required by alignment work. It makes possible to directly connect source points of network with points being defined during designing core networks process.

Firstly, for some networks it is necessary first of all to ensure required accuracy in determining coordinates of points relative to starting points.

One of the options for creating backbone network is shown in Fig. 4. It can be used when creating planning justification for construction of bridges, where it is necessary, first of all, to ensure regulatory accuracy of coordinates of determined points relative to reference points (Methodology, 2024; Rysbekov, 2024).

опорная сеть – geodetic network

исходные пункты- reference point

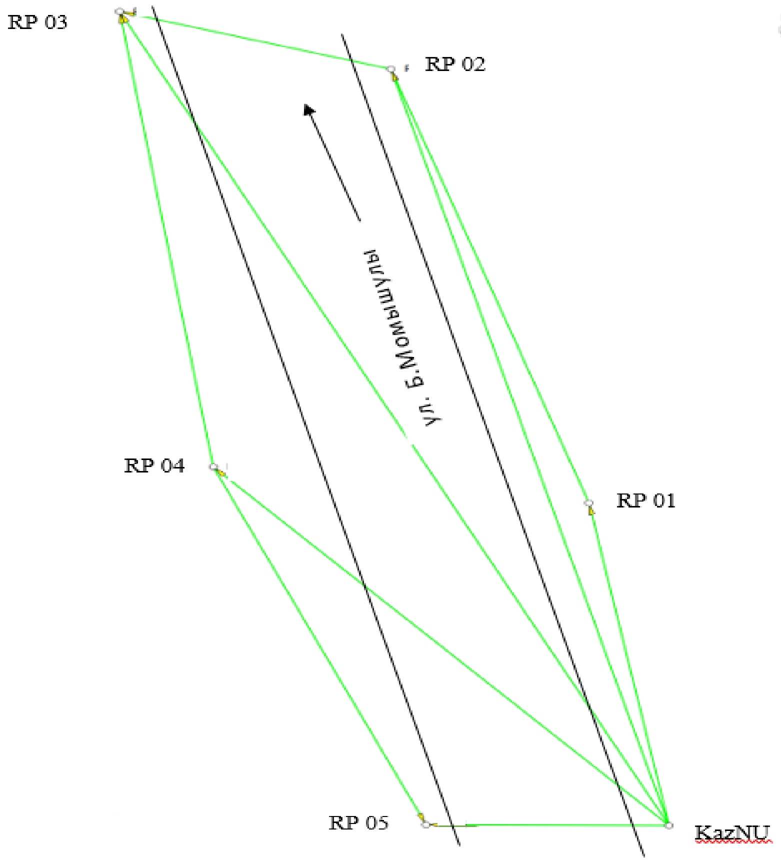

Figure 3.- Scheme of geodetic network of the transport interchange

To obtain accurate coordinates of planned altitude justification of network, it was decided to use GNSS equipment, and it was necessary to perform static measurements. Satellite measurements were carried out in Static mode; work in this mode implies conditional division into two stages: field work and desk processing.

Traditional approach to using GNSS technology is to determine the coordinates of geodetic network points, adjust measurement results in a geocentric coordinate system, and then convert them into geodetic coordinates (B, L) and then into rectangular zonal coordinate systems. Traditional approach ensures the main principle of measurements – their unity. However, it is known that position accuracy of geodetic network points located significantly from axial meridian is significantly distorted in the UTM or Gauss-Kruger projection. In addition, determining coordinates in adjacent areas of zones is quite labor-intensive. These problematic issues are largely resolved using proposed method of using topocentric coordinates.

Points coordinates obtained using GNSS technology are very convenient to transfer to local topocentric surface and use them during construction. In this case, point O (x,y,z) - origin of coordinate system, is located on the earth's surface (Mustafin et al., 2019). This point, as a rule, should belong to central zone of geodetic reference network. Height H_0 is the height of reference surface most suitable for designing construction work. Advantage of this approach offer the possibility to convert geocentric coordinates to local horizontal surface with minimal plan distortions, and height calculations can be carried out separately and also with accuracy control. Thus, development of such technique will improve accuracy during performing geodetic work during survey and construction

Technique for converting coordinates from geocentric system to a local topocentric system is possible from expression (Younes, 2017):

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = R^T \begin{bmatrix} X - X_0 \\ Y - Y_0 \\ Z - Z_0 \end{bmatrix}, \qquad (1)$$

where (x y z)T – coordinates in topocentric system; (X Y Z)T – coordinates in geocentric system; (X0 Y0 Z0)T – coordinates in geocentric system and B0, L0 – geodetic coordinates of the reference network point. R – transformation (reversal) matrix:

$$R^T = \begin{bmatrix} -\sin B_0 \cos L_0 & -\sin B_0 \sin L_0 & \cos B_0 \\ -\sin L_0 & \cos L_0 & 0 \\ \cos B_0 \cos L_0 & \cos B_0 \sin L_0 & \sin B_0 \end{bmatrix}. \qquad (2)$$

From (2) we see that (x, y) do not depend on their geodesic height. Control point will be network beginning e in the local topocentric coordinate system (KazNU). This point can be selected in the way that it coincides with specific point in network or with point whose coordinates coincide with coordinates of gravity center of reviewed surface and also coincides with a point whose height is equal to average height of all points in network. It makes it possible to vary location of topocentric surface to achieve optimality during solving specific problem (Ormanbekova et al., 2015; Kyrgizbaeva et al. 2017).

Converting geocentric coordinate system into a local topocentric coordinate system when using GNSS technologies has simple algorithms that allowing accurately determine position of point on the earth's surface without reducing accuracy. Procedure for converting from the WGS-84 coordinate system to local coordinate system is shown schematically in Figure 5:

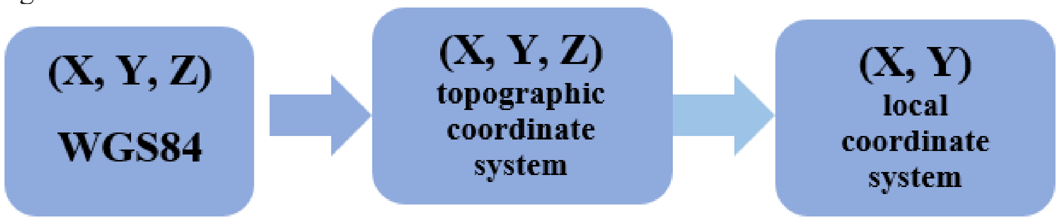

Figure 4 – Scheme for converting WGS-84 coordinates to local ones through topocentric coordinate system

Conversion is carried out in several stages:

Stage 1. For points of reference engineering and geodetic network for construction, spatial rectangular coordinates (X, Y, Z) are determined using GNSS technologies, which are converted into geodetic coordinates (B, L, H).

Stage 2. Coordinates of GNSS measurement points are converted from geocentric coordinate system to local topocentric coordinate system.

Stage 3: Based on coordinates of reference points of network, for which coordinates in local coordinate system (x', y') are known, conversion parameters to a topocentric system are calculated using Helmert's formulas. Coordinates of network points at which GNSS measurements were performed, and converted into topocentric coordinate system, are combined with local coordinate system used for design and implementation of geodetic work during construction (Balandin et al., 2016; Kuanbayeva et al., 2024: 1640–1647; Abakumov et al., 2014: 209–218). Next, using calculated transformation parameters, coordinates of remaining points are recalculated into local construction coordinate system.

During field work, three GPS receivers from the Swiss company Leica GS16 were used - 2 receivers and one GPS1200 receiver. Measurements were carried out in 3 sessions of satellite observations. Duration of each session was at least 5 hours, and start of observation session was taken as the time when the last GPS receiver was turned on. The KazNU benchmark served as the main benchmark for planned height justification.

Static raw data from the «KazNU» base station was processed in BERNESE Version 5.2 software relative to the world base stations BADG CHUM KIT3 POL2 TASH URUM ZECK and obtained geographical and rectangular coordinates in ITRF2014 results of which are given in Tables 1-4.

Table 1-Geographical coordinates of WGS84 GRS80 Ellipsoid, ITRF2014

Station	Latitude (D M S)	Longitude (D M S)	Ellipsoid Height(m)	Height above Geoid EGM2008 (m)
KAZNU	43 14 29.67445	76 49 46.18375	736.558	780.937

Table 2 - Rectangular coordinates UTM43 GRS80 Ellipsoid, ITRF2014
Universal transverse Mercator projection

Station	Y (m)	X (m)	Zone	Ellipsoid Height (m)	Height above Geoid EGM2008 (m)
KAZNU	648535.227	4789266.883	43	736.558	780.937

Table 3 - Cartesian coordinates, ITRF2014

Station	X (m)	Y (m)	Z (m)	ITRF2014
KAZNU	1060445.327	4531724.011	4347595.735	19/06/2024

Next, after receiving the coordinates of the «KazNU» point relative to it, the following benchmarks of the planned altitude justification RP1, RP2, RP3, RP4, RP5 were processed.

Linking points RP1, RP2, RP3, RP4, RP5 of the network to the KazNU point ensured high accuracy and consistency of the obtained coordinates and altitudes with the World Coordinate Base I and the WGS84 coordinate system. Also, to increase the accuracy of the final results before processing, the project included such data as accurate satellite ephemeris, ionospheric maps, maps of the state of the troposphere and updated satellite clocks for the period of field work (Table

Table 4 - Results of processing satellite measurements.

Points name	X(m)	Y(m)	Z(m)	X C K O (m)	Y C K O (m)	Z C K O (m)
KazNU	1060445.452	4531728.015	4347600.247	0.001	0.002	0.002
RP01	1060450.826	4531590.719	4347735.415	0.005	0.009	0.009
RP02	1060498.443	4531397.788	4347918.332	0.002	0.004	0.004
RP03	1060613.531	4531346.441	4347942.316	0.002	0.004	0.004
RP04	1060614.238	4531536.745	4347750.107	0.002	0.004	0.004
RP05	1060553.076	4531701.593	4347599.740	0.003	0.007	0.006

The accuracy of determining the normal height of points according to GNSS technology at any point must ensure the condition

$$m_{h_i} \leq \mu\sqrt{L}\,, \tag{3}$$

where L is the average distance from the base point «KazNU» I to reference point i.
Calculation results are presented in Table 5 and Figure 6.
Method of direct geodetic measurements when transmitting marks has the following se-

quence. Geodetic points (RP01, RP02, RP03, RP04 and RP05) are installed on the earth's surface and geometric leveling and satellite determinations are carried out. This will be the basis for constructing a model of the quasi-geoid surface. Calculation results are presented in Table 5.

Table 5 – Accuracy of transfer of marks when using geometric leveling method and measurement method using GNSS technology

Building height, m	Mean square errors (mm)	
	Geometric method	GNSS technologies
0	2,6	10,0
25	4,6	10,0
50	6,0	10,1
...	...	...
175	10,3	10,9
200	10,9	10,2

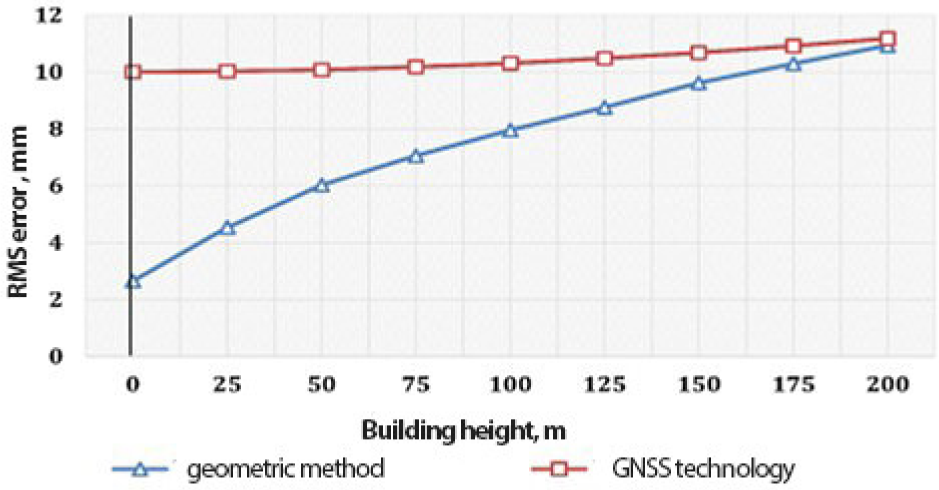

Figure 5 – Error diagram for determining marks

From Fig. 5 it can be seen that up to height of 200 m, geometric (ground) method makes it possible to more accurately transfer elevations to installation horizons. At the same time, use of GNSS technology gives approximately same accuracy.

Numerical examples show that accuracy of determining elevations using GNSS technology is practically independent of building height. This is especially important during construction of high-rise structures. At the same time, calculations have shown that the transmission of elevations is not as effective with the use of GNSS technologies, especially at heights up to 200 m.

The use of this data in post-processing made it possible to eliminate main sources of errors that arise when performing satellite measurements. And also increase accuracy of final results, that is, coordinates and heights of identified points. Position of initial benchmarks in the created observation system is determined by linear-angular intersections from the points of the reference geodetic network.

Conclusions

1. Existing few studies on GNSS adjustment mainly deal with geodetic coordinates and solutions for large networks. Choice of suitable plane coordinate system for geodetic work during construction is understudied. Analysis of methodology for creating planned support network for construction of long-distance bridges was carried out.
2. Choice of reference surface is justified when creating geodetic support networks for construction of long-distance bridges in seismic areas;
3. Analysis of features of processing satellite measurement results when creating geodetic reference networks was carried out;
4. Technique has been developed for converting coordinates from the WGS84 or GRS90 system to local coordinate system, using surface of reference at the height of construction site;

Thus, scientific problem associated with development of methodology for creating support networks for construction of long-distance bridges in seismic areas using satellite technologies has been completely solved. Accuracy analysis confirmed correctness of selected solutions.

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