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THE IMPLEMENTATION OF ROAD DESIGN ENGINEERING SURVEY STUDIES BY SATELLITE AND ELECTRONIC TECHNOLOGIES

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Abstract

The basic geodetic networks created for engineering geodetic surveys of road construction are presented using polygonometric and satellite technics. The key components of the route, the horizontal and vertical circular curves, and the marking work to move them to the site are all provided. Both the satellite technic using GPS satellite receivers and the polygonometric method of building fundamental geodetic networks were taken into consideration. It has been grounded that the satellite method, which, when used, reduces human resources, saves financial resources, and shortens the time of work implementation, is the most efficient way to build fundamental geodetic networks.

Keywords: electronic tachometer, GPS satellite receiver, fundamental geodetic network, horizontal and circular vertical curves.

Introduction

In general, research in the field of road construction engineering focuses on ensuring the security of users of transportation services and road segments during all phases of development, thorough repair, upkeep, reconstruction, and operation.

The implementation of two main types of work - topographic surveys and digital terrain models, as well as the gathering and analysis of existing topographic and geodetic resources (various scale plans, profiles, etc.) are all parts of geodetic surveys of highways.

Design work comes before research work. Engineering geodetic research is defined as a body of work that offers topographical and geodetic resources for the design, construction, or reconstruction of linear structures.

Engineering surveys give information about the terrain and local conditions, and they serve as the foundation for other types of research in addition to design.

Preliminary regulatory and technical documents are provided in the current applicable norms for the design and implementation of planar geodetic basic networks for the routes of linear structures [1–5].

The creation of geodetic plan and elevation networks is being done in order to guarantee the precision of engineering geodetic surveys. They serve as the foundation for topographic research at various scales. The axes of planned linear structures serve as the foundation for planar grid design and construction. On the basis of these networks, numerous tasks are completed, including sthe routing of linear structures, their construction, and the plan-elevation connection of geological and geophysical exploration points.

Currently, satellite methods are used to create the geodetic plan and elevation base for surveying new railways and roads, building main canals and collector pipelines in populated areas, and field routing. With a relative error of 1/5000 of linear measurements, $\pm 10''\sqrt{n}$ angular measurements, and $\pm 50\sqrt{L}$ (mm) height offsets, compaction of satellite networks can be accomplished using traditional methods, where ***n*** is the number of track angles, and ***L*** is the length of the track in km.

The road's path is known as the axis of the projected linear structure, and it is fixed to the landscape and depicted on a topographic map or orthophoto map, a digital representation of the terrain with the coordinates of its key features.

The main elements of the route are the plan - its projection on the horizontal plane and the longitudinal profile - the vertical cut along the projected line (Fig. 1).

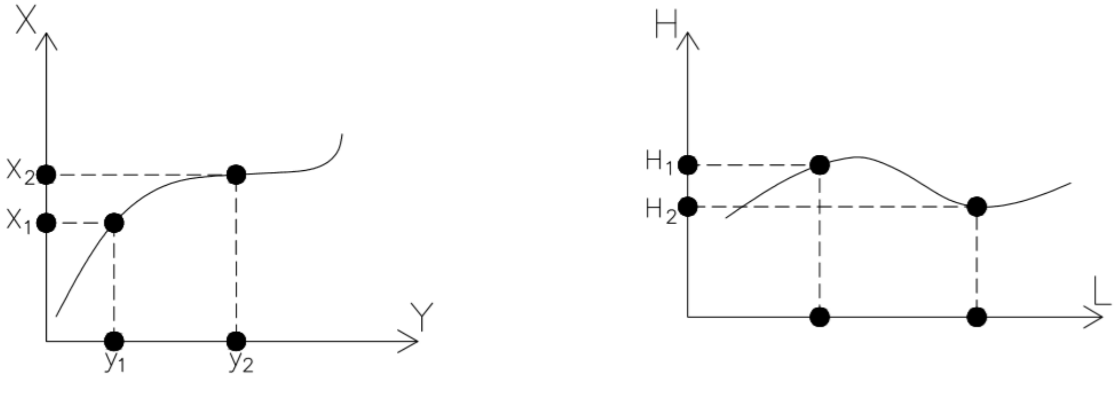

Fig 1. Plan and side view of the route

The highway is an intricate spatial line. It is composed of straight sections in various directions that are joined to one another by horizontal curves with different curvature radii (Fig. 2). The route in the longitudinal profile is made up of lines with various slopes blended bwith vertical circular curves. Fig. 3 illustrates the primary components of circular curves based on the route category and terrain conditions, the curve radius R is chosen; the lengths of tangent lines AC=BC=T also known as tangents, are as follows

$$T = R \cdot tg\frac{\theta}{2} \tag{1}$$

The length of the curve $AFB = K$

where

$$K = R \cdot \pi \frac{\theta^\circ}{180^\circ}: \tag{2}$$

The length of the bisectice $CF = B$

where

$$B = R(sec\frac{\theta}{2} - 1) \tag{3}$$

The values of doms

$$D = 2T - K \tag{4}$$

Curve tables are created using the above formulas for R and θ data.

Point C is known as the vertex of the turning angle (BY), while points A, B, and F are the curve's beginning (HK), middle (CK), and end (KK), respectively.

The listed points are referred to as the curve's key elements. A unified coordinate system called stationing is used to divide the routes of linear structures into equal sections. As a rule, the lengths of these sections are equal to 100 m, of which endpoints by stakes are fixed in the site and they are given names by the stakes. The beginning of stationing usually starts from zero.

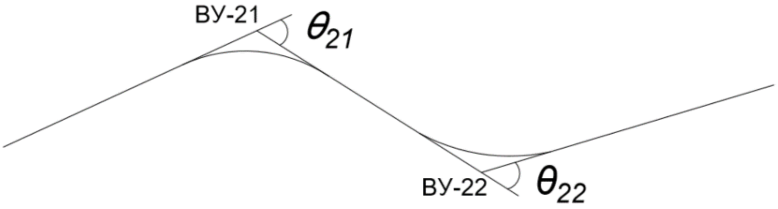

Fig. 2. Elementa of the route plan

The following formulas are to calculate the picket values of the curve's major points.The following formulas are used to calculate the picket values of the curve's major points

$$\begin{cases} HK = BY - T \\ KKc = cHK + K \\ CK = HK + \frac{K}{2} \end{cases}, \tag{5}$$

where KK is the end of the curve, HK is the beginning of the curve, BY is the vertex of the angle of turn, T is the length of the curve, and CK is the curve's midpoint.

Straight sections of road tracks coincide with circular curves using so-called transition curves. Following the main version of the route's approval, a basic plan and elevation geodetic network are built along the research highway under design.

Basic plan and elevation geodetic networks are created by triangulation, polygonometric and teletitation (satellite) technics. During the research, this network serves as the basis for taking the project into the site to create large-scale topographical mapping of transport and station junctions, road junctions and complex topographic sections of the highway. The geodetic network serves as a plan for carrying out elevational surveying work during construction, moving the route's elements to the site with coordinates and elevation marks.

Conflict Setting

The triangulation method is not recommended given the current capabilities of using digital geodetic tools and equipment because the technical requirements for building such networks require a lot of manual labor. Based on the above, the task is set to demonstrate the construction of fundamental geodetic networks applying polygonometric and satellite techniques.

Research Results

It is advisable to create basic geodetic networks using electronic tacheometers in a polygonometric manner. The state geodetic network and the national geodetic network's starting points, whose coordinates were determined by satellite, were used to create the basic geodetic networks using the polygonometric method.

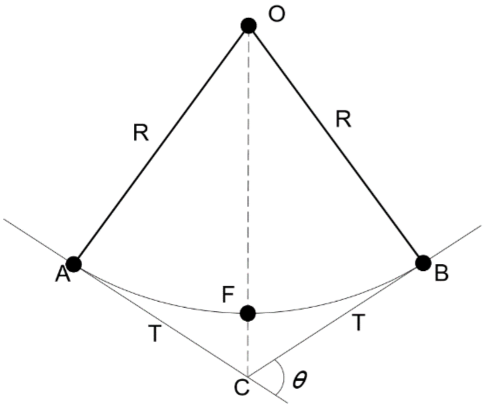

Fig. 3. Elements of cirgular curves

Since high-class roads are designed to be as short and tight as possible, polygonometric courses will also have turning angles of less than 20º. Let's assess the precision of a polygonometric course that is six km long and based on upscale landmarks with precise coordinates. Let's now by the below formula to assess the course accuracy

$$M^2 = m_s^2 \cdot n + \frac{m_\beta^2}{\rho^2} L^2 \frac{n+3}{12} , \tag{6}$$

where m_S is the mean squared error of lines measurment, m_β is the mean squared error of angles measurment, ρ is the radian measure in seconds.

Let us assume that the average length of the course sides is 500 m and that the number n of the course's sides is 12 [6].

When using electronic tacheometers to measure distances, the maximum measurement error in this case will be 10 mm. When measuring the lengths of the sides of polygonal courses, the errors can be as high as 5 mm for lines 500 m in length, The first term of the formula (6) can be interpreted as the longitudinal displacement of the polygeometric process (the longitudinal displacement of the process t's end point), and the second term as the transverse displacement, given that the main processes are close to highly stretched ones (the transverse displacement of the end point of the process u). then we get

$$t^2 = m_s^2 n; \quad u^2 = \frac{m_\beta^2}{\rho^2} L^2 \frac{n+3}{12} \ . \tag{7}$$

Substituting the numerical values given above, we will get t = 35 mm; u = 335 mm. The combined effect of angular and linear measurement errors is $M=\sqrt{(t^2+u^2)}=337$ mm.

Since the weakest point of a polygonometric course based on known points is located in it, the root mean square error of the weak point will be about 170 mm or 0.17 m. Bearing in mind that the mean square error of the coordinates of the reference points of such a network is relative, the error of the reference points of the basic network should not exceed 0.35 m [8, 9].

Basic geodetic networks are built using dual-frequency GPS satellite receivers in satellite technics.

In the Republic of Armenia, a national geodetic network in a unified coordinate system was established in the years 2002 to 2004 using the WGS-84 world geodetic coordinate system. There are only 1236 points in total, 5 of class 0, 41 of class 1, 1190 of class 2, and one point for every 24 km^2 of country territory [9].

A network of 12 permanent operating reference stations, with an accuracy of less than one centimeter in the eastern and northern components and up to 2.5 centimeters in the altitudinal component, was established in 2013. $M = \sqrt{t^2 + u^2} = 337мм.$

Eight reference points of the national geodetic network, including four of class 0 and four of class 1 reference points, are connected to the network of permanently operating reference stations.

Based on the aforementioned, we can conclude that a network of continuously operating reference stations, with a static observation mode lasting 20–40 minutes, ensuring high accuracy, can be used to create the engineering geodetic basic condensation network for road design. We can estimate the accuracy of the basic geodetic network created by satellite using the following formula

$$M^2 = m_1^2 + m_2^2 \ , \tag{8}$$

where m_1 and m_2 are the mean squre errors of the output and observation, respectively.

Substituting the value of the mean square errors of the output and observed data in formula (8), we will have 1.7 cm.

In the absence of a network of permanently operating reference stations, the basic engineering geodetic networks are created by the differential observation method. Equipment is installed at a minimum of two reference points, such as A and B, when using the differential method. A base or reference station is one of them.

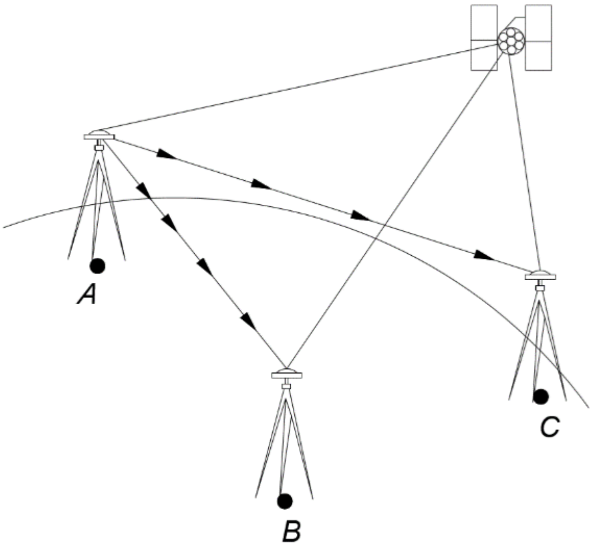

Fig. 4. Relative measurement scheme

No corrections are determined, but differences are generated from station observations. In statics, using multiple distortion-free differences, the space vector *D* connecting these stations is calculated:

$$D=\sqrt{\left(X_B-X_A\right)^2+\left(Y_B-Y_A\right)^2+\left(Z_B-Z_A\right)^2}. \tag{9}$$

Thus, in relative measurements, the coordinate increments between the base and target points are determined, so the base vector is an important component for such measurements. It is a three-dimensional vector of coordinate increments between the reference and target points.

The coordinates from the reference point are transferred to the target through the baseline. These transfer errors depend on the length of the baseline and directly include errors in the coordinates of the output datum.

It is advised to use a base line between 5 and 15 km long when building geodetic networks of compaction. To determine the coordinates of the remaining geodetic grid points from the measured elevations, the base station's coordinates must be precise.

The formation of discrepancies between the coordinates of the base and target points is what gives relative measurements their high accuracy.

In the joint processing of observations, systematic errors for all receivers have approximately the same values, which are corrected during simultaneous distance measurements. These include ephemeris and time scale errors of the same satellite, errors of tropospheric and ionospheric effects.

The almanac is utilized to forecast static observations. The most accurate and time-consuming approach is the static approach. Depending on how long the measurements are, the method's accuracy can vary. The accuracy of measurements is to the nearest decimeter within 5 minutes. Typically, the duration of observations at a pair of stations is about one hour. During this time, the accumulation of measurement results takes place at intervals from one second to five minutes.

When tracking at least five satellites, most receiver systems have the following root mean square errors (D is the distance from the base station in kilometers):

- in plan (5 + 1 x D km) mm with D less than 10 km,
- in plan (5 + 2 x D km) mm with D more than 10 km,

- in height (10 + 2 x D km) mm.

The most precise and straightforward method of creating geodetic grids is static observation mode. It takes up the most time. The observation time can range from one hour to several hours, depending on the level of precision required for coordinate determination. Post-processing and specialized software are used in static mode.

Additionally, the locations where the receivers will be installed are picked so that the satellite signals won't interfere with nearby landmarks. It shoul be as exposed as possible to the horizon of the sky.

The length of the baseline measurement, the accuracy standards, and the receiver type all affect the estimated observation time.

The duration of the observations is determined by the need to fully resolve the uncertainty of the phase measurements. For dual-frequency receivers, ambiguity resolution is performed within 10...15 minutes, even on long bases. This period of time might be adequate for single-frequency receivers only on short baselines of up to one km. Long-term observations lasting at least an hour are necessary for the resolution of uncertainty for long baselines. The information in the Table below can be used to project an approximate observation time. Long observation time increases the accuracy of coordinate determination. With high accuracy requirements, measurements are planned for several sessions (runs), including repeated measurements, returning to the decision points [6, 8, 10, 11].

Table

Estimated observation time

Length of baselines, km	Number of sessions, minutes
0,1…1,0	10…30
1,1…5,0	20…60
5,1…10,0	20…90
10,1…30,1	30…120

After analyzing the aforementioned, it is clear that the development of engineering geodetic basic geodetic survey networks for the design of roads created by satellite is the most efficient satellite method, as it results in a reduction in the need for human resources, financial resources, and work time.

Conclusion

Basic geodetic networks should be established by satellite technology in developed and undeveloped areas where the sky is visible to satellites. Large-scale topographic plans can be made and updated using satellite methods. Marking design elements and other geodetic work can also be done using coordinates obtained by an automated system, which ensures high accuracy and reliability and eliminates human error. Electronic tacheometers are used in those areas where the observation of the sky is not sufficient or is densely built or it is impossible to place GPS receivers. In other words, in the conditions of complex situations and relief of the regions, combined technics are used.

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ՃԱՆԱՊԱՐՀՆԵՐԻ ՆԱԽԱԳԾՄԱՆ ԻՆԺԵՆԵՐԱԳԵՈԴԵԶԻԱԿԱՆ ՀԵՏԱԶՈՒՈՒԹՅՈՒՆՆԵՐԻ ԻՐԱԿԱՆԱՑՈՒՄՆ ԱՐԲԱՆՅԱԿԱՅԻՆ ԵՎ ԷԼԵԿՏՐՈՆԱՅԻՆ ՏԵԽՆՈԼՈԳԻԱՆԵՐՈՎ

Պետրոսյան Հ.Ս.[1], Համբարձումյան Պ.Վ.[1, 2], Զաքարյան Ս.Հ.[2], Խանանյան Վ.Ա.[2]

[1]Ճարտարապետության և շինարարության Հայաստանի ազգային համալսարան

[2]Շուշիի տեխնոլոգիական համալսարան

Ներկայացվում է ճանապարհների կառուցման հիմնային գեոդեզիական ցանցերի ստեղծման պոլիգոնոմետրիական և արբանյակային եղանակները: Բերվում է ճանապարհների նախագծման փուլերի, ուղեգծի հիմնական տարրերի, հորիզոնական և շրջանաձև ուղղաձիգ կորերի և դրանք տեղանք տեղափոխելու նշահարման աշխատանքների սխեման: Դիտարկվում է հիմնային գեոդեզիական ցանցերի ստեղծման պոլիգոնոմետրիական եղանակն, օգտագործելով էլեկտրոնային տախեոմետրեր և GPS արբանյակային ընդունիչներ: Հիմնավորվել է, որ հիմնային գեոդեզիական ցանցերի ստեղծման ամենաարդյունավետն՝ արբանյակային եղանակն է, որի կիռարման դեպքում կրճատվում է մարդկային անհրաժեշտ ռեսուրսները, խնայվում է ֆինանսական միջոցները, կրճատվում է աշխատանքների իրականացման ժամանակը:

Բանալի բառեր. էլեկտրոնային տախեոմետր, GPS արբանյակային ընդունիչ, հիմնային գեոդեզիական ցանց, հորիզոնական և շրջանաձև ուղղաձիգ կորեր:

ПРОЕКТИРОВАНИИ ДОРОЖНЫХ ИНЖЕНЕРНО-ГЕОДЕЗИЧЕСКИХ СЕТЕЙ СПУТНИКОВЫМИ И ЭЛЕКТРОННЫМИ ТЕХНОЛОГИЯМИ

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Представлены полигонометрические спутниковые методы построения опорных геодезических сетей для инженерных изысканий дорожного строительства. Учитывая этапы проектирования дорог, основные элементы трассы, горизонтальные (круговые), вертикальные кривые разбивычных работ по перенеснию их на местность. Рассмотрен полигонометрический метод построения опорных геодезических сетей с использованием электронных тахеометров, спутниковый метод с использованием GPS спутниковых приемников. Обоснован, что наиболее эффективным способом создания опорных геодезических сетей является спутниковый метод, позволяющий сократить человеческие ресурсы, сэкономить средства и сократить время работ.

Ключевые слова: электронный тахометр, GPS спутниковый приемник, опорная геодезическая сеть, горизонтальные и круговые вертикальные кривые.

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