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APPLICATION OF SATELLITE NAVIGATION SYSTEMS IN OBSERVATION OF LANDSLIDE PHENOMENA

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Abstract
This paper discusses the study of modern conditions and the problem of landslide phenomena in rocks by their types. The conditions and reasons for the formation of landslide areas are considered. It is shown that, subject to a number of necessary conditions, a landslide is, first of all, a function of the steepness and height of the slope, and only then a function of the presence of groundwater. The issues of using modern satellite navigation systems in monitoring landslide phenomena are considered. Methods for observing landslide phenomena using modern satellite systems are presented. Based on the results of satellite navigation observations of signs installed on the surface of the landslide, the magnitude, direction and speed of horizontal and vertical displacements were calculated. The accuracy of the specified characteristics has been assessed.

Keywords: Oblzn, satellite navigation, slope, sediment, relief, landslide terrace, deformation, horizontal, vertical displacement, forward, inverse, linear intersections, polygonametry, alignment, GPS, static method, cnimatic method, pseudocnimatic method, ionosphere, coordinates of points.

Introduction
Today it has become an irrefutable truth that one of the main problems of our time has put forward the problem of protecting people and their environment from the

consequences of emergencies caused by natural disasters, accidents and catastrophes, including those of an environmental nature.

The nature of Uzbekistan is generous: high mountains, deep rivers, large sandy massifs and oases of gardens. At the same time, the climatic and geological features of the territory of the republic, as well as the infrastructure of sectors of the national economy, determine the possibility of natural emergencies: earthquakes, floods, mudflows, landslides, snow avalanches, possible breakthroughs of hydraulic dams and high-mountain lakes and the formation of catastrophic zones in connection with this flooding.

Correctly and undetermined displacement of a landslide area in a timely manner can lead to an irreparable disaster, with the destruction of agricultural crops, a unique natural landscape and even human casualties (Fig. 1).

Thus, we are faced with the problem of correctly and timely determining the displacement of landslide areas. This problem can be solved using modern geodetic methods and using satellite navigation systems to determine the movement of landslides.

According to the definition of I.V. Popov, a landslide is the displacement of rock blocks with a volume of tens of cubic meters or more on steep slopes as a result of wetting of the separation surfaces with groundwater [2,7]. It is the rock blocks that slide, while retaining (within the blocks) their original structure. Sliding rocks are usually loose or poorly consolidated. The sliding block may contain separate layers or lenses of strong rocks.

Literature and method

Landslides occur on a slope or slope due to an imbalance of rocks caused by an increase in the steepness of the slope as a result of erosion by water, weakening of the strength of rocks due to weathering or waterlogging by precipitation and groundwater, the impact of seismic shocks, as well as construction and economic activities, without taking into account the geological conditions of the area (destruction of slopes by road excavations, excessive watering of gardens and vegetable gardens located on slopes, etc.).

The size of landslides varies greatly. There are huge landslides involving hundreds of thousands of cubic meters of rock, and small landslides of several tens of cubic meters. Therefore, the main task when organizing the protection of the population and territories from landslides should be a coherent structure to prevent their negative impacts [3].

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Rice. 1. Collapse caused by natural causes.

Fig2. Heavy rains hit Southern California (USA).

Landslides are usually confined to steep slopes of ravines, gullies, and river valleys. They are found in the mountains in the area of development of weakly cemented rocks. Landslides are widespread on platform plains, where they are confined to the banks of rivers and seas. But everywhere on the plains, landslide slopes occupy small areas due to the fact that generally steep slopes (more than 15 degrees) are narrowly localized and the percentage of the territory occupied by them to the total area of the plain is not even 1%. In the mountains, strong rocks predominate, which also sharply limits the spread of landslides. On the plains, as well as in the mountains, in places where rocks emerge, even on the steep slopes of valleys, landslides are not observed.

During a landslide, a certain complex of relief forms is formed: a landslide circus, limited by the landslide failure wall (landslide ledge), a landslide block, characterized in most cases by the tilting of the upper area (landslide terrace) towards the landslide slope with a steep ledge facing the river, sea or lake in the direction of the landslide movement. The landslide separation surface has a spherical shape, tending to approach a circle. In some cases, as a result of deformation of the surface layers of rock by a moving landslide block, a pressure landslide shaft appears. Such landslides are called detrusive, in contrast to delusional ones, which slide freely to the river edge.

Discussion

Observations of landslides. Observations of landslides are carried out using various geodetic methods. Depending on the type and activity of the landslide, the direction and speed of its movement, these methods are divided into four groups [2,7]:

- axial (one-dimensional), when the displacement of points fixed on the landslide is determined in relation to a given line or axis;
- planned (two-dimensional), when displacements of landslide points are observed along two coordinates in the horizontal plane;
- vertical – to determine only vertical displacements;
- spatial (three-dimensional), when they find the total displacement of points in space along three coordinates.

Axial methods are used in cases where the direction of movement of the landslide is known. These include [4,8]:

- distance method, which consists in measuring distances in a straight line between signs installed along the movement of the landslide;
- method of sites equipped in the direction perpendicular to the movement of the landslide;
- beam method, which consists in determining the displacement of the landslide point by changing the direction of the sighting beam from the original sign to the landslide one, while the angular parameters between these directions are measured.

Planned methods include direct, backward, linear intersections, polygonometry, and a combined method that combines the measurement of directions, angles, distances and deviations from alignments.

Altitudinal displacements of landslide points are found mainly by geometric and trigonometric leveling methods[1].

To determine the spatial displacement of landslide points, photo theodolite survey is used.

At the present stage of scientific and technological progress, satellite measurement methods are widely used in geodetic production. We propose the use of GPS measurements as a spatial method for determining the displacement of landslide points. The use of the NAVSTAR GPS satellite navigation system is more effective than

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photo theodolite survey, both in terms of accuracy and economic indicators. In addition, labor productivity increases by simplifying the production process.

Displacements of landslide points are calculated in relation to support signs, which must be located outside the landslide area. The number of signs, including landslide ones, is determined for reasons of ensuring a high-quality measurement scheme and identifying all the characteristics of the ongoing process.

Observations of landslides are carried out at least once a year. The frequency is adjusted depending on the fluctuation in the speed of the landslide: it should increase during periods of activation and decrease during periods of extinction.

Results

As a result of the rapid development of scientific and technological progress, especially in recent decades, a new method for determining coordinates and their increments has emerged - satellite. It uses moving satellites whose coordinates can be determined at any time.

Currently, two satellite navigation systems are used: the American system NAVSTAR GPS Navigation System with Time And Ranging Global Positioning System (navigation system for determining distances and time, global positioning system) and the Russian satellite system GLONASS - Global Navigation Satellite System.

To solve various problems: determining the exact coordinates of individual points, sequential measurements of the location of many points, continuous coordinate determinations, etc., a number of measurement methods have been developed within the GPS framework. These methods differ in the technology of performing the work and the resulting accuracy of calculating the base vector.

Static method (Static Positioning)

The name of the method means that the receivers do not move during the entire observation interval. The base receiver and the unknown receiver simultaneously observe and record data for 15 minutes to 3 hours. This session duration is caused by the need to determine the integer phase ambiguity at the beginning of the session. This is also facilitated by a noticeable change in the configuration of the satellite system over time. Single-frequency receivers are used to measure bases up to 10-15 km long, and dual-frequency receivers are used for bases longer than 15 km (the advantages of dual-frequency receivers are the ability to adequately simulate the effect of the ionosphere, as well as shorter observation durations to achieve a given accuracy). After completing the observation sessions, the data received by each

receiver is collected together, entered into a computer and processed using special programs in order to determine the unknown coordinates of points.
This method is used to solve problems of monitoring national and continental geodetic networks, monitoring tectonic movements of the earth's surface, monitoring the condition of dams, foundations of nuclear power plants and other structures.

Pseudo-Static Positioning
It differs from static in that it provides higher survey productivity by performing observations over several short sessions instead of one long one. One receiver continuously monitors the base station. The transported receiver, after observing for 5-10 minutes at the designated point, is turned off and transported to the next designated point, where it is turned on again for 5-10 minutes. Then it turns off again and is transported to the next point, etc. Each designated point must be visited again for 5 minutes 1 hour after the first visit.
This method is almost equivalent to the static method, but instead of waiting 1 hour for the satellites' configuration to change, observations are made for 5 minutes and the next 5 minutes are observed one hour later when the configuration has changed significantly. The remaining 55 minutes can be used to visit additional unknown destinations. The accuracy of the results obtained will be at the level of the static method.
Both single-frequency and dual-frequency receivers can be used for observations[6]. The method is convenient when it is necessary to accurately measure the coordinates of a large number of points within a short time. The disadvantage of the method is the need to accurately plan the schedule of visiting points[5].

Rapid Static Positioning
This method has been developed in recent years. It has significantly increased the productivity of GPS surveys. The method differs from the pseudostatic one in that only one visit to the determined points is sufficient (within 5-10 minutes - depending on the distance between the reference and determined points). At first, at the stage of the emergence of this method, only dual-frequency P-code receivers were suitable for observations. Nowadays, some single frequency receivers can also be used in fast static mode.

Stop-and-Go Kinematic Positioning
The method allows you to obtain the positions of points as quickly as in the case of using an electronic total station when solving topographic problems. The method

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requires a short initialization procedure to determine integer phase ambiguities. After this, the reference receiver continues to continuously observe at a point with known coordinates, the second receiver is transported (on) to the first determined point, where it again observes for 1 minute. Then he visits all other designated points (only once).

The most common initialization procedures are:

exchange of antennas, when the second receiver is located at the “exchange point” (knowledge of its coordinates is not necessary), selected at a distance of no more than 10 m from the reference one, observation of 4-8 epochs is performed, then the receivers are rearranged (without turning off), exchanging antennas and observing 4 -8 epochs (up to several minutes), and then the reverse procedure for exchanging antennas and performing observations for 4-8 epochs occurs;

standing of the second receiver for 1 minute at the second point with known coordinates, and this second point can be at a distance of no more than 10 km from the reference point;

static method, when the determined point is selected at a distance of no more than 10 km from the reference point, and the observation session lasts at least 30 minutes.

The method is effective when performing topographic surveys, when it is necessary to determine the coordinates of a large number of points in a short time, when constructing digital terrain models, and determining the location of terrain objects that have the shape of a broken line (pipelines, roads, etc.).

Kinematic method with static initialization

The method is very similar to the previous one. In the same way, at a base point with known coordinates, an initialization procedure is performed, then the mobile receiver moves to the starting point of the movement route and makes observations there for several minutes. Next, the moving platform with the receiver begins to move along the route. GPS measurements are performed continuously while driving at intervals of 1 second. The accuracy parameters of the method are the same as those of “Stop-and-Go”. Most often used to obtain coordinates of linear objects such as roads, rivers, etc.

Kinematic method with on-the-fly initialization

This method does not require the placement of a mobile receiver at the base station for initialization - this procedure is performed directly while the vehicle is moving along the route. In addition, if for any reason the observations are disrupted, the initialization process is carried out again without stopping the movement. The

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accuracy parameters and areas of use of the method do not differ from other kinematic methods.

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