Journal of Engineering and Applied Sciences 14 (6): 1781-1785, 2019
ISSN: 1816-949X

Soil Slope Stability During Maintaince of Hydraulic Structures

R.B. Ismuratova, A.I. Sultanbekova and A.A. Krivchenko
Kostanay Engineering and Economics University named after M. Dulatov,
Chernishevskogo Str. 59, Kostanay, Kazakhstan

Abstract: This study considers the problem of soil slope stability near the hydraulic structures. This problem is important because there are requirements for ensuring the sustainability of the constructed and finished objects and there is methodology and results of instrumental determination of the disturbed massif condition with the use of geodetic methods the studies determined the value of benchmarks movements in soil. The problem of soil slopes stability has always been the most urgent as the soil slopes are constantly encountered in the construction of hydraulic complexes, hydroelectric power stations, roads, civil facilities, etc. They exist in open excavation and embankment of the soil or in a cut and fill. Variable external conditions (humidity, temperature) affect the soil slopes they transform physical and mechanical characteristics of the soil and it clearly affects their stability.

Key words: Hydroelectric power station, benchmark, deformation, tension, compression, embankment

INTRODUCTION

The destruction of the individual slopes are events that are usually less devastating and ruinous than some other catastrophes but they are more common and the total damage from the destruction of slopes is more substantial than losses from a single destructive natural processes. It should be added that a large part of the damage is due to landslides caused by earthquakes and floods. The issues of ensuring the stability of slopes are the subject of numerous studies by engineers and geologists. In recent years, great progress has been made in studying the geomechanical characteristics of soils and their influence on the stability of slopes (Nguyen, 2013).

Many hydrotechnical facilities are located in regions with abundant precipitation. As a result, the mass of soil slopes (in the construction of hydraulic structures, roads, civilian objects) slide under the influence of anomalous precipitation, their destruction as is known can lead to large human casualties and huge material damage. Manuel Trejo Soto (Moscow) in 2007 pointed out in his research (Manuel, 2007) that the construction of large technical structures such as dams, bridges and high-rise buildings is essential for the development of any nation. Significant deformations of engineering structures, close to critical can potentially cause the death of a large number of people and severe destruction. The preservation and durability of buildings is an important national economic task and it depends not only on the scientifically grounded construction of these structures but also on the completeness of the investigation of soils on which structures are built on the account of the influence on the structures of the external environment and in particular on the timely setting and correct implementation of systematic observations of the state of structures.

Consequently, the safety of these works, especially in the case of dams, requires periodic monitoring and a comprehensive analysis of their structural state, based on a large set of variables that contribute to these deformations. In fact, the notion of deformations itself forms the subject for monitoring. Several factors determine the deformation of these structures. None of the modern large constructions can not do without systematic observations of soil settlements and displacements of structures using geodetic methods. The results of observations of settlements and displacement of engineering structures by geodetic methods must meet the requirements for completeness, timeliness and accuracy. The largest hydroelectric power station in the Caucasus is the Inguri hydroelectric power station, located on the Inguri River on the way to upper Svaneti. The dam separates the Jvar reservoir, the volume of which is 1.1 billion m^3 of water. Several small landslides occurred on the slopes near the reservoir and on one side of the lake there is a huge landslide “Khoko”, the fall of which in the reservoir will cause an emergency situation. Very high seismicity due to the fact that the area is located at the foot of the mountain belt of the greater Caucasus as well as a number of active earth breakages located from

Corresponding Author: R.B. Ismuratova, Kostanay Engineering and Economics University named after M. Dulatov, Chernishevskogo Str. 59, Kostanay, Kazakhstan

Georgia to the Caspian Sea. Despite the fact that seismicity can increase tilt instability and cause landslides no dynamic analyzes of the stability of the slopes surrounding the reservoir have been carried out.

MATERIALS AND METHODS

The main methods for measuring soil settlements and deformations of engineering structures are geodesic. They allow us to determine not only the relative displacements of points but also their absolute magnitudes due to practically fixed signs of the geodetic justification. Observations of sediments and deformations of structures occupy a significant place in the modern practice of engineering and geodetic works. The volume and complexity of observations and the requirements for their accuracy increase from year to year. In connection with this, special methods and means of measurement are being developed. The choice of the method and the process of geodetic observations are determined by the constructional features of the structures and the specific conditions. To observe precipitation and deformation of large engineering structures, the most specific methods are used. In the study of various kinds of deformations arising in the Earth's crust as well as in the bases of hydroelectric power stations and other objects it becomes necessary to perform fairly frequent (and sometimes continuous in time) measurements.

Fundamental (initial) benchmarks, included in the high-rise foundation of the dam are located outside the zone of possible deformations of bedrock that occur as a result of the construction of hydraulic constructions and the filling of the reservoir (Kuznetsov and Krupin, 2001). It is more preferable to place them on the outputs of bedrock, located on unflooded marks at points remote from landslide and karst sites, places of tectonic faults and soils that are prone to expansion or soil settlement. Observations of the deformations of landslides and potentially unstable arrays are carried out with the help of reference, plan and high-altitude geodesic signs, the arrangement of which has been previously established by visual observations and investigations. Benchmarks and strongholds should be located behind the contour of a landslide or potentially unstable massif. The direction of the alignment is usually taken perpendicular to the direction of motion of the landslide. Settlement of marks that are established in characteristic and accessible for observation points of a landslide and potentially unstable massif isdetermined by means of geometric and trigonometric leveling. Tacheometric survey (in conditions of difficul visibility when cutting through forest or in complex terrain) in the alignment of long straight lines intermediate theodolites are provided from which continuation of the alignment is carried out.

To eliminate the collimation error, the most distant milestone is set twice with two half-strokes with the final setting in the middle between the two initial positions. The theodolite which is installed in place of this milestone iscentered within 1 cm. Intermediate milestones are established by the "self" method.

RESULTS AND DISCUSSION

Comparison of the modern spatial coordinates of the network with the coordinates determined at the beginning of the work allows us to determine the total shift vectors-shift trends. Shift trends can be both natural (caused by tectonic movements along the boundaries of structural blocks) and anthropogenic (caused by the redistribution of tensions and deformations in the massif under the influence of groundwater and other factors).

On the road Zugdidi-Mestia that is 36-38 km long, 14 control points were established on the body of the landslide to measure the dynamics of its movement due to the danger it poses to the Jvari reservoir and accordingly, to the Inguri Dam. Control benchmarks are made of metal, installed at a depth of 1 m in the ground (Fig. 1).

The control points are numbered and divided into the following categories; RP-stationary points that are located outside the landslide body, MST-mobile control points (in the landslide body) and ST points for leveling the measurements of the total station (Fig. 2).

To determine the coordinates in the global coordinate system we used a high-precision GPS device Leica, the coordinates of points ST1 and SST were measured with high accuracy.

The location of the above points was determined after a visual inspection of the territory and an open terrain was chosen for optimal communication with satellites. Measurements of the frames were made with a high-precision geodetic device with a total station Leica TS11.

With the help of high-precision geodetic instruments (total station Leica TS11 and GPS geodetic equipment) two series of instrumental measurements of benchmarks were carried out in in years 2015 and 2016 (Fig. 3).

Horizontal deformation interval for the period between two observations is determined by Eq. 1 (Nguyen, 2013):

$$\alpha = \frac{\alpha 2 - \alpha 1}{\alpha} \quad (1)$$

where, α, $\alpha 1$, $\alpha 2$ is the horizontal length of the interval from the initial, previous (Eq. 1) and subsequent (Eq. 2) observations.

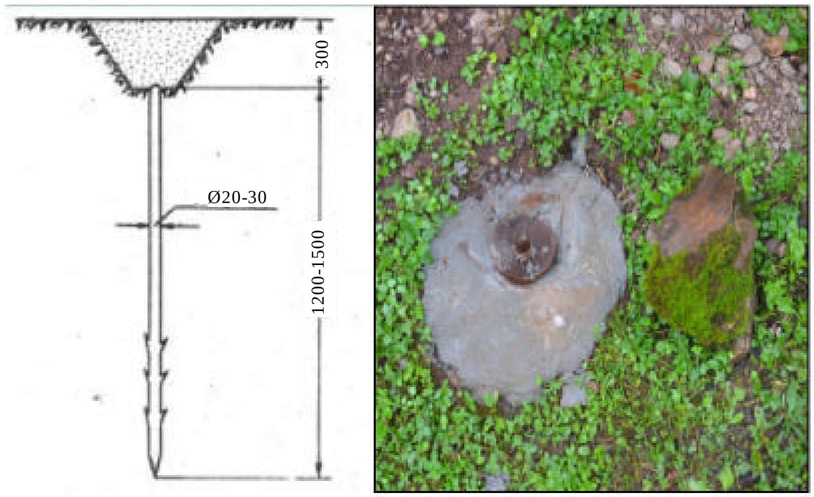

Fig. 1: The benchmark

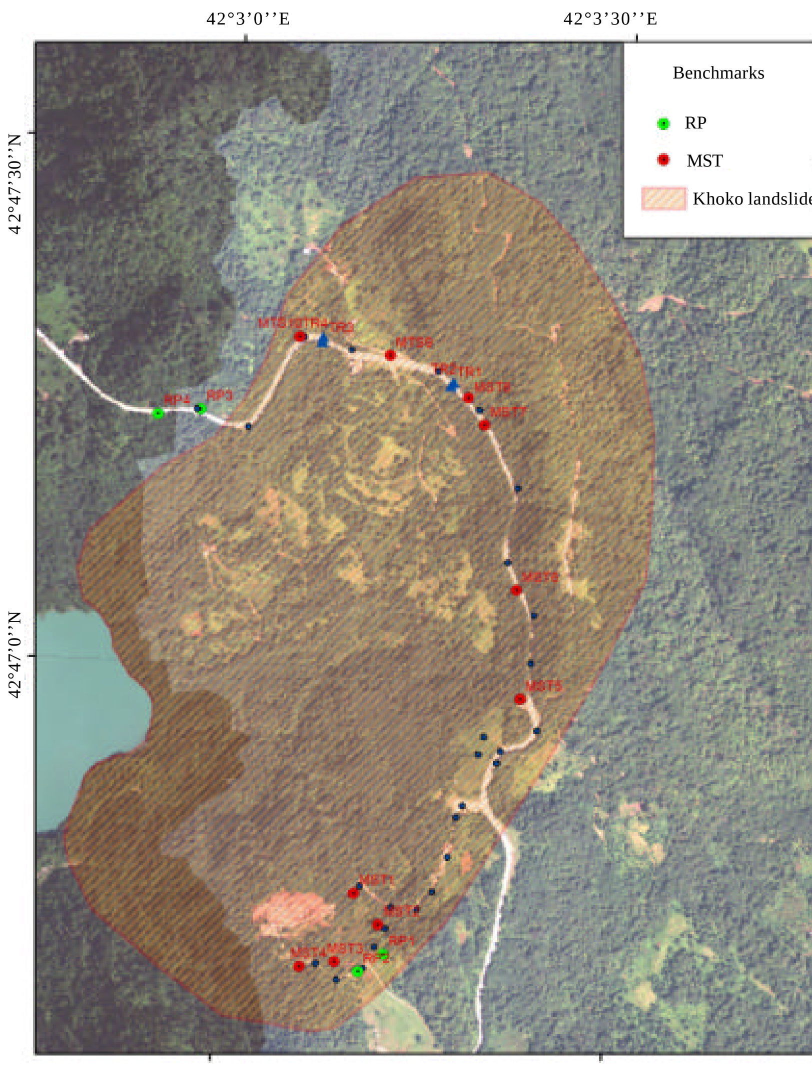

Fig. 2: Benchmarks location map

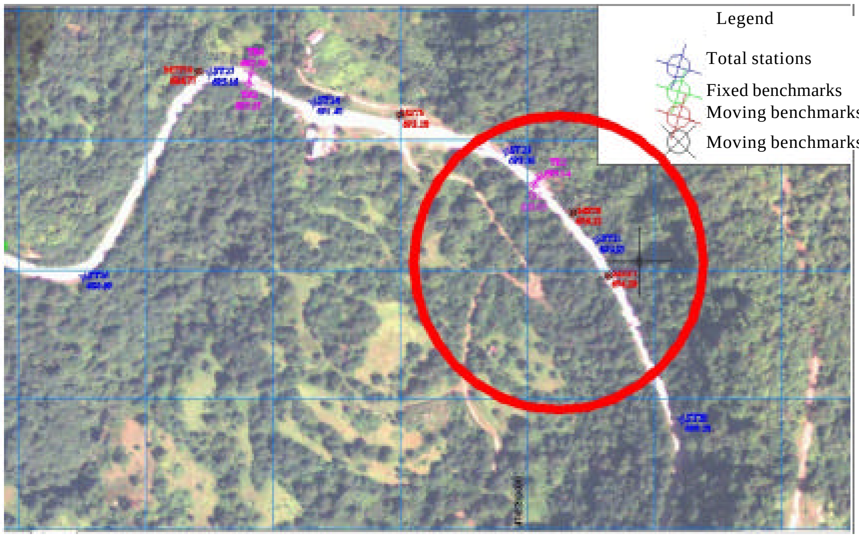

Fig. 3: Instrumental measurement of benchmarks

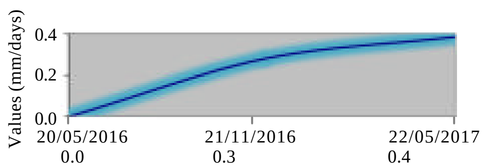

Fig. 3: Rp7 (Row)

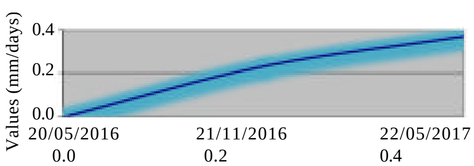

Fig. 4: Rp8 (Row)

Horizontal deformations over the entire observation period, from the initial to the present, are determined by the Eq. 2 (Manuel, 2007):

$$\alpha = \frac{\alpha n - \alpha}{\alpha} \quad (2)$$

where, αn is the horizontal length of the interval from the given observation. Horizontal deformations corresponding to an increase in the interval are denoted by the sign "+" and are called stretches and those corresponding to decreasing intervals are negative "-" and are called compressions.

The calculated horizontal distances between the benchmarks (by summing them) determine the distances from the supporting benchmark to each of the profile line benchmarks that fit into the horizontal displacement statement.

When processing observation materials along a profile line, the horizontal displacements E (mm) are determined by the following Eq. 3 (Kuznetsov and Krupin, 2001):

$$E = D2 - D1 \quad (3)$$

where, D_1, D_2 are the Distances from the supporting benchmark to the given benchmark from the initial (or previous) observation and from the subsequent observation. Horizontal and vertical displacements can also be calculated from differences in the lengths of intervals and exceedances between adjacent benchmarks in the compared series of observations (Eq. 4).

According to the displacement of the benchmarks, the values of the shifts in the area of the rock massif are compiled (Bergsten *et al*., 1996). The magnitude of the shift γ is defined as the ratio of the difference of the total displacements of nearby benchmarks to the distance between these benchmarks along the normal line to the direction of their displacement Eq. 4:

$$\gamma = \frac{\Delta bn+1 - \Delta bn}{m} \quad (4)$$

Where:

Δb_{n+} = The total displacement of the front benchmark
Δb_n = The total displacement of the rear benchmark
m = The distance between the benchmarks along the normal line to the direction of displacement of the vectors (Beukema, 1987)

The magnitude of the shift is referred to the middle of the interval. Table 1 and 2 show the results

Table 1: Benchmark displacement list

	Month May 2016			Month November 2016			Displacment values		
Benchmarks name	x	y	z	x	y	z	x	y	z
MST1	258934,966	4740567,225	718,864	258934,963	4740567,219	718,863	-3	-6	-1
MST2	258977,631	4740511,772	742,917	258977,615	4740511,793	742,869	-16	21	-48
MST3	258901,364	4740446,050	745,217	258901,384	4740446,056	745,197	20	6	-20
MST4	258840,213	4740437,699	755,819	258840,204	4740437,674	755,810	-9	-25	-9
MST5	259226,077	4740910,277	713,860	259226,074	4740910,279	713,935	-3	2	75
MST6	259219,748	4741103,261	703,011	259219,722	4741103,252	703,085	-26	-9	74
MST7	259163,979	4741395,853	694,293	259163,977	4741395,824	694,336	-2	-29	43
MST8	259136,238	4741443,930	693,235	259136,234	4741443,902	693,274	-4	-28	39
MTS9	259000,036	4741519,465	693,193	259000,031	4741519,431	693,216	-5	-34	23
MTS10	258841,703	4741552,807	684,780	258841,709	4741552,787	684,802	6	-20	22

Table 2: Benchmark displacement list

	Month May 2016			Month May 2017			Displacment values		
Benchmark name	õ	y	z	õ	y	z	õ	y	z
MST1	258934,966	4740567,225	718,864	258934,966	4740567,257	718,870	3	38	7
MST2	258977,631	4740511,772	742,917	258977,615	4740511,793	742,871	0	0	2
MST3	258901,364	4740446,050	745,217	258901,378	4740446,047	745,190	-6	-9	-7
MST4	258840,213	4740437,699	755,819	258840,208	4740437,665	755,809	4	-9	-1
MST5	259226,077	4740910,277	713,860	259226,076	4740910,277	713,889	2	-2	-46
MST6	259219,748	4741103,261	703,011	259219,702	4741103,238	703,044	-20	-14	-41
MST7	259163,979	4741395,853	694,293	259163,928	4741395,789	694,300	-49	-35	-36
MST8	259136,238	4741443,930	693,235	259136,193	4741443,865	693,241	-41	-37	-33
MTS9	259000,036	4741519,465	693,193	259000,013	4741519,393	693,193	-18	-38	-23
MTS10	258841,703	4741552,807	684,780	258841,711	4741552,777	684,797	2	-10	-5

of the studies and control measurements of the benchmarks produced at different times of the year.

Inference: From graphic documents (Table 1 and 2), we can draw the following conclusion; the volumetric displacement is most noticeable in benchmarks 7 and 8. It is this zone that represents the greatest potential danger, since, the most probable is the realization of the accumulated tension in the array.

CONCLUSION

New coordinates will be measured during the next field work which is planned every 6 months. Further displacement will be analyzed at stationary points which will give us an overall picture of the dynamics of the landslide motion and the motion diagram will be constructed. This research will enable us to assess the danger and risks associated with the activation of the landslide.

This stage is aimed at geodetic measurements to identify and locate potential active faults. Determination of horizontal and vertical displacements in the road section near the location of the hydroelectric power station.

Accordingly, the obtained data will be used later to determine the rates of movement of the massif along tectonic disturbances and to assess the impact of mining operations on the development of the geodynamic situation as a whole which ultimately will allow certain forecast estimates to be made and take appropriate measures to prevent the catastrophic consequences of technogenic activity of Inguri hydroelectric power station.

REFERENCES

Bergsten, H., K. Nordberg and B. Malmgren, 1996. Recent benthic foraminifera as tracers of water masses along a transect in the Skagerrak, north-eastern North Sea. J. Sea Res., 35: 111-121.

Beukema, J.J., 1987. Influence of the predatory polychaete Nephtys hombergii on the abundance of other polychaetes. Mar. Ecol. Prog. Ser. Oldendorf, 40: 95-101.

Kuznetsov, V.S. and V.A. Krupin, 2001. [Recommendations for conducting natural observations for draft]. MSc Thesis, VNIIG, St. Petersburg, Russia. (In Russian)

Manuel, T.S., 2007. [Development of a technique for analyzing the results of geodetic measurements in the observation of soil settlements and displacements of large engineering structures by satellite methods]. Ph.D Thesis, Moscow State University of Geodesy and Cartography, Moscow, Russia. (In Resian)

Nguyen, F.D., 2013. [Stability of slopes of GTS pits during rainfall infiltration]. Ph.D Thesis, Peter the Great St. Petersburg Polytechnic University, Saint Petersburg, Russia. (In Resian)