

# Comprehensive geotechnical monitoring of the landslide processes and the retaining structures in the city of Sochi

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**ABSTRACT:** When constructing the important structures in the landslide hazardous areas, it is necessary to carry out geotechnical monitoring. A program of comprehensive geotechnical monitoring of the landslide plots at "Agura" interchange in the city of Sochi is given in the present article. The development project observation results being obtained have been analyzed. The data being obtained prove an acceptable operation of the structures.

## 1 INTRODUCTION

The natural climatic conditions, the lithologic-and-structural features of the rocks, which form the slopes, and an anthropogenic influence promote the development of many landslide phenomena on the Black Sea coast of Krasnodar Territory. A landslide displacement of soils is a result of a multiple influence of the natural and technogenic factors and can be prepared during many years or can take place in the process of an initial mastering of the slope (Matsiy, 2010). The engineering-geological process of a formation and development of the landslide displacements is far more complicated than the mathematical models, the design diagrams and the graphs. In reality, there always exist the unsuspected uncertainties, which are connected with an inconstancy of the soil features and an imperfection of the design methods, which give only a mechanical solution of the natural task (Matsiy & Bezuglova, 2010). It results in the frequent accidents both at the stage of construction and the operation of the landslide protection structures. Carrying out of geotechnical monitoring is one of the most effective methods of the landslide risk management. A constant observation of the situation makes it possible to carry out the necessary corrections of the design solutions in due time and to put additional measures concerning the engineering protection into effect.

## 2 OBSERVATION OBJECT

Within the framework of the wide-ranging preparation for the Sochi 2014 Olympic Games, an alternate route of Kurortny Prospect is being constructed; it will decrease an intensity of the traffic infrastructure of the city. The highway is situated along the sea coast slope with an exit to a ridge, which separates the seaside and a valley of the river Agura. One of its main points is situated at an

interstream area of Agura-Bzugu where Obkhod (the Bypass) of the city of Sochi and A-147 highway Dzhubga-Sochi are met. This area is in the low mountain part of the sea coast under the complicated engineering-geological conditions where there are according to the list of state monitoring service two ancient landslides No. 214 and No. 215.

The landslide No. 214 has a slightly knobby surface, forested parts; its area is nearly 9000 m<sup>2</sup>, its approximate thickness is 14 to 16 m. Small erosion insets with the deepness of 0.5 m in the clay soils are observed; they are caused by temporary waterways. The surface morphology of the landslide No. 215 is a small stepped one as well; the breakaway brows have the dimensions up to 1 m; the area is nearly 14000 m<sup>2</sup>, its thickness is 8 to 10 m. The landslide bodies consist of the deposits with an insignificant capture of the bedrock. They are at the stage of a long-term stabilization, which has resulted in a formation of the powerful landslide strata in the floor of the valley. But in the course of construction, a large scale level of a microblock displacement activation hazard remains at the points of a coincidence of the surface inclines and the bedrock stratification. A construction of a pile anchor landslide protection structure is envisaged in order to protect from an influence of the hazardous geological processes (Figure 1).



Figure 1. Pile anchor landslide protection structure at the interchange in the area of the city of Sochi

### 3 GEOTECHNICAL MONITORING PROGRAM

At the design stage of the protection measures, a comprehensive geotechnical monitoring system was worked out; its implementation began in June, 2009, together with the geotechnical survey. Its main task is a prevention of the emergency situation development at the interchange being considered as well as an assessment of sufficiency and effectiveness of the protection solutions being adopted (Figure 2 & 3).

Within the framework of the program, the scheduled route observations of the site are carried out monthly. They are aimed at an ascertainment of the changes in geomorphology and the landscape geobotanical conditions as well as a check of the design solution fulfilment quality. The total extension of the route is more than 1 km; 30 station points are situated here. In order to measure the construction displacements, 63 marks are put; they are plugs with the washers. The geodetic base stations are arranged. The marks are situated at the borders of the deformation sections in pares at the same vertical. Their position in plan and from top to bottom is determined with the help of an electronic tachometer monthly. The landslide accumulations are mapped with

the help of the methods of seismic profiling and electric profiling as well. A complex use of various methods makes it possible to obtain more complete and detailed information concerning the processes, which take place at the site. A position of the geophysical profiles for various cycles remains unchanged. The surveys are carried out quarterly.

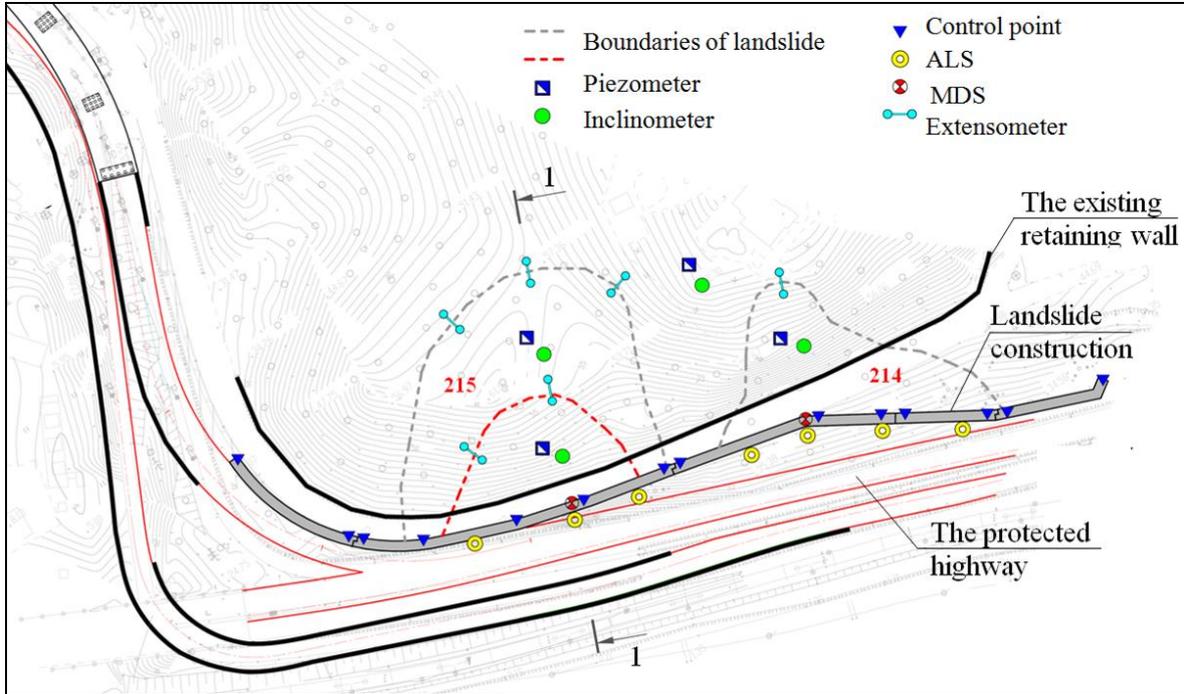


Figure 2. Layout of geotechnical equipment at "Agura" interchange

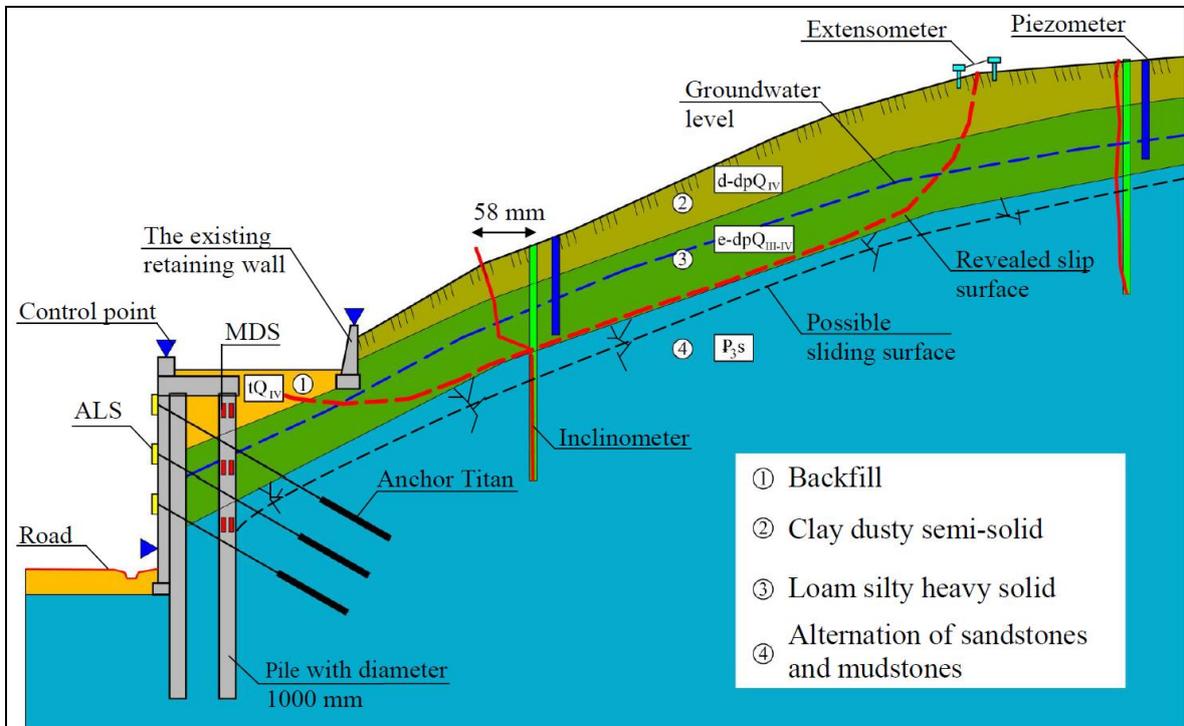


Figure 3. Layout of equipment in section 1-1 at "Agura" interchange

The depth displacements of soil are observed with the help of five deviation recording wells, which have the depth of 14 to 18 m. They are arranged at the borders of the existing landslide systems as well as at the places of their possible development. In order to observe the ground water level, the pressure observation wells with the depth of 10 m are arranged nearby. As vegetation is dense, it is impossible to arrange a network of the monuments in order to trace the surface displacements at this part. For this purpose, a system of 6 surface extensometers is used; they are embedded in concrete at the depth of 0.4 m. A landslide pressure influence on the structure is assessed with the help of the mechanical deformation sensors (MDS), which are arranged in two most loaded piles. The sensors are placed in pares in the sections, which are arranged with spacing of 4 m (Figure 4). The anchor load sensors (ALS) were mounted using bolted connections. When they were arranged, the anchors were tightened up to the design stress of 200 kN. Equipment was installed mutually by the specialists of the manufactures: the open joint-stock company “Avangard” (city of St.-Petersburg) and “SisGeo” (city of Milan). When the installation was finished, the readings were taken twice a week during two months; then the inquiry interval was changed according to the elaborated program. Information concerning weather conditions and past precipitation quantity is granted by the Sochi weather station. Total quantity of the equipment being installed and the interval of the readings are given in Table 1.

Table 1. Quantity of the geotechnical equipment being installed

| Name                          | Quantity                      | Interval of readings |
|-------------------------------|-------------------------------|----------------------|
| Inclinometer                  | 5 wells, total length of 80 m | fortnightly          |
| Piezometer                    | 5 wells, total length of 50 m | half-weekly          |
| Extensometer                  | 6 pieces                      | fortnightly          |
| Anchor load sensors           | 21 pieces                     | fortnightly          |
| Mechanical deformation sensor | 12 pieces                     | fortnightly          |

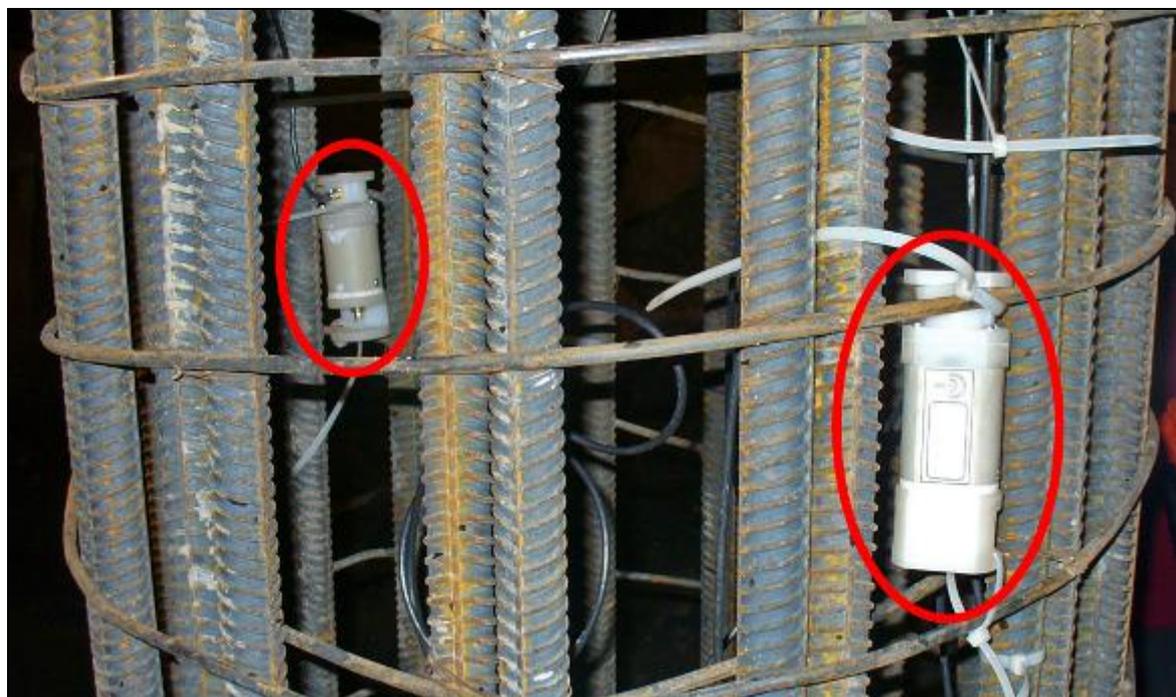


Figure 4. MDS installation in the body of a cast-in-place pile

#### 4 ANALYSIS OF FINDINGS

The results, which were obtained during the geophysical investigations, made it possible to specify the borders of the landslide parts and to define the area of filtration and increased fissuring. The seismic exploration data demonstrated the presence of irregularities and an increase of longitudinal wave velocity at the depth of 5.5 to 7 m in the area of the landslide No. 215; it proved instability and watering of the present zone.

According to the meteorological data, the precipitation was 126.9 mm in March, 2011; it exceeds the norm by more than 20%. It resulted in a significant rise of the ground water level and an activation of the tongue part of the landslide No. 215 along the border of bedding of loams and argillites. It was proved by the data, which were obtained from inclinometer I-4, which total displacement was more than 60 mm, as well as the readings of piezometer P-4 situated at the depth of 8 m (Figure 5). At that period, a small increase of load (within the limits of 25 kN) was registered at the anchor load sensors ALS-4, 5 and 6, which were arranged at an axis of the displacement being supposed (Figure 5). It is a bit more than 2.5% from the carrying capacity of the anchor and exerts practically no influence on the operation of the whole structure. No significant changes in the stressed state of the piles being observed were detected.

The analysis of the geodetic measurements showed that small deformations at that part of the wall were registered from March 16 till April 2, 2011. Maximal values of the vectors of the planned displacements did not exceed 9 mm. At other parts, the readings remained within the limits of the device accuracy. During the visual investigations, the landslide activity signs were registered, i.e. the deformations of the existing retaining rubblestone wall and the fresh soil stripping brow with the height of 0.3 to 0.5 m. In order to track them, additional extensometric ranges were installed. It is necessary to note that the visual manifestations of the landslide activity took place only this day month after the inclinometric pipe displacement beginning. After spring, intensive precipitation stopped; it resulted in a gradual stabilization of the situation.

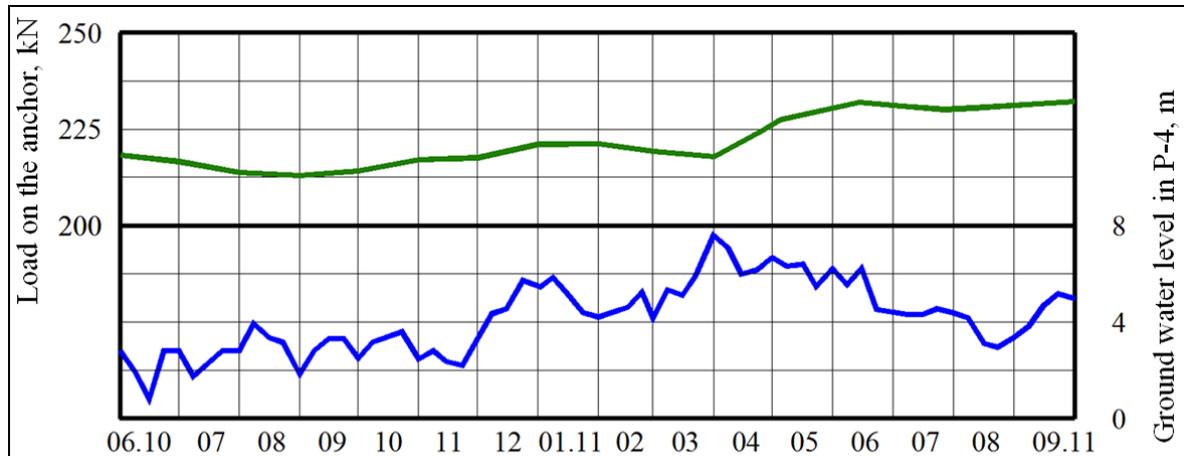


Figure 5. Load change at ALS-4 and position of ground water level in piezometric well P-4

#### 5 CONCLUSIONS

The data being obtained prove that the landslide protection structure has an adequate carrying capacity margin. No additional measures are required; it is more expedient to evacuate the soil, which droops from the upper part, because the upper road will not be used when the construction is over. Further observations will make it possible to provide the long-term forecasts of the state of the landslide hazardous masses and the engineering structures in order to prevent the possible emergency situations. Thus, it is possible to make a conclusion that the elaborated comprehensive geotechnical monitoring system provides a completely trouble-free operation of the interchange

being considered. The instrumental observations make it possible to register the changes, which take place in the landslide mass body, much earlier than their visual signs appear. In some cases, it can become a decisive factor when an emergency situation occurrence should be prevented and a significant material damage can be caused.

## REFERENCES

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