Geotechnical Monitoring of the Automobile Road

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Abstract. In the present article, the results of geotechnical monitoring of A-147 automobile road “Dzhubga-Sochi” are given. Some sections of the automobile road suffered from the landslide adjustment movements; it resulted in many deformations of the retaining structures, the damages of the roadbed and ground crawling over the retaining walls. The observation data made it possible to specify the borders of the active landslide and to form a forecast of the landslide activity in the sections of the automobile roads. Due to monitoring being carried out, there was substantiated the necessity to correct the service forms and records connected with the automobile road reconstruction.

1. Introduction
In the year of 2010, a sequence of the landslide adjustment movements took place at the 196-th kilometre of A-147 automobile road “Dzhubga-Sochi”. It resulted in an emergency situation in some sections of this highway installation. The landslide activity caused a significant damage to the existing retaining structures and the roadbed. In the period of the preparation for 2014 Winter Olympic Games, some temporary measures of the engineering protection were suggested in order to prevent an emergency situation. But the motions of ground masses resumed; it caused the new significant constructive damages of the structures and impugned a safe operation of the part of the installation. Geotechnical monitoring is necessary to provide safety and rigidity of the highway installations [1]. That’s why an observation of that section was arranged in order to find the regularities of the adjustment movement changes as far as time is concerned and their connection with various landslide forming factors.

2. Arrangement of temporary strengthening of the structure
The landslide adjustment movements took place in A-147 highway installation “Dzhubga-Sochi”; as a result, the ground crawled over the retaining walls. The significant deformations of the retaining structures are given in figure 1. There were found the damages of the roadbed in the form of the wide cracks; they are given in figure 2. The registered adjustment movements were seasonal and were connected with excessive moistening of the ground surface layer of the overlying landslide body.

Before the beginning of the restoration work, the retaining walls were strengthened with the help of the temporary structures employing the solid concrete blocks. In order to restore the operation condition of the automobile road in the section, 2 rows of the anchor piles of Titan type were designed.
The computations, which have been made employing GeoStudio program complex [2], have demonstrated that stability of the slope is provided ($K_s > 1$), but it is not sufficient ($K_s < 1.2$) (figure 3); the foreseen measures perform the functions connected with the emergency event liquidation completely and an elimination of the emergency state of the existing strengthening structures. In case of the earthquake loads or a natural condition change, the landslide processes as well as the deformations of the retaining structures and the roadbed can become active.
In order to eliminate the possibility of force-majeure, the anchor sensors being given in figure 4 were installed. Thanks to it, it became possible to check the stress changes in the structures of strengthening of the existing retaining walls. The readings were registered twice a day; it would make it possible to take the necessary measures quickly in case of need.

Figure 3. Slope stability computations - the second phase of the project

Figure 4. Anchor sensors: a - the general view; b - the estimation of the readings
In the year of 2016, the anti-landslide measures in the landslide dangerous sections were designed in order to provide a maximum safe operation. It was decided to erect the pile anchor retaining walls at the 196-th kilometre.

3. Geotechnical monitoring at the installation
A geotechnical monitoring network was implemented at the installation in order to observe the dangerous geological processes, which took place as a result of the increased anthropogenic influence. Within the geotechnical monitoring framework, the following tasks were implemented: a visual observation, the geodesic and geotechnical supervisions (directional surveying in the wells, a data acquisition of the strength measuring plates and the linear deformation sensors) as well as the geophysical investigations.

During the observations of the 196th kilometre of A-147 automobile road “Dzhubga-Sochi”, 5 most dangerous sections were found; the manifestations of the landslide adjustment movements were detected there. The anchor sensors, which were earlier installed at AS-2 and AS-3 retaining structures, became unfit for use in 5 years; that’s why they were installed anew.

By virtue of the surveying observation cycle being performed, there were found the displacements, which came up to 2 to 6 cm. At the section of AS-4 anti-landslide structure, the final displacement of the benchmark from the initial position was 127 cm.

According to the deviation measurements, which diagrams are given in figure 5, many ground movements were found. The detected deformations correlate with the visual and geodetic observations.

According to the data of I-8 deviation recording well arranged in the Sukhumskoe highway, the adjustment movements, which came up to 30 mm, were detected at the depth of 5 m at the head part of the landslide body in transit of AS-4. According to the deviation recording wells arranged in the summit slope relatively to AS-5, the surface displacements with thickness up to 2 m were registered. According to I-9 well, the displacements with the size of up to 25 mm began from the depth of 2 m; according to I-10 well, they began from the depth of 2.5 m.

According to the data of I-11 deviation recording well arranged in the summit slope in the area of the deformations of AS-1 existing wall, the horizontal displacements of the ground solid were found. At the depth of 7 m, the displacements amount to 3.5 mm; at the depth of 3 m to 0.5 m, the total adjustment movements amounting to 15.5 mm at the base of the well are registered. Thus, two landslide surfaces with the depth of occurrence of 3 m and 7 m have been found.

AS-1 section at 195+248.69 to 195+353.99 km is the most dangerous one. The deformations of the existing structures were registered there, according to the visual observation results; the geodetic measurements proved the visual observation results. According to the deviation recording observations, a slip surface with the depth of 7 meters, which comes out to the case of the existing wall, was marked.

At the rest monitoring sections, the insignificant displacements being connected with the civil engineering work were detected. Monitoring, which was carried out, made it possible to specify the landslide situation and to correct the service forms and records for the construction.

4. Conclusions
In the year of 2010, the landslide adjustment movements and the deformations of the retaining structures took place at the 196th kilometre of A-147 automobile road “Dzhubga-Sochi”. Close to 2014 Olympic Games in Sochi, the top-priority measures, which eliminated the emergency situation, were carried out. In the year of 2015, the permanent anti-landslide measures were worked out; their implementation began in the year of 2016. Geotechnical monitoring was carried out at the section during construction. Geotechnical monitoring results made it possible to specify the borders of the active landslide, to form a forecast of the landslide activity at the automobile road sections and to correct the service forms and records for the automobile road reconstruction.
Figure 5. Cumulative diagrams of the deviation recording wells: a - I-10 well in AS-5 area; b - I-11 well in AS-1 area

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