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Results of comprehensive monitoring activities on Umka landslide, Belgrade, Serbia

Biljana Abolmasov[1], Uroš Đurić[2]
[1]University of Belgrade, Faculty of Mining and Geology, Serbia, biljana.abolmasov@rgf.bg.ac.rs
[2]University of Belgrade, Faculty of Civil Engineering, Serbia, udjuric@grf.bg.ac.rs

Background

The Umka landslide is the deepest and biggest active landslide in the Republic of Serbia and has been investigated and monitored by different geotechnical techniques for decades. This paper will be focused on results and experience gained from automated Global Navigation Satellite System (GNSS) monitoring network data, PSInSAR data analysis from Sentinel1 radar satellite images, conventional geodetic monitoring network data and UAV imaging, processing and data analysis in the last six years.

Study area

The Umka landslide is formed on the right Sava river bank, 22 km southwest from Belgrade, and occupies part of Belgrade suburban settlement Umka. Geometry, geological settings, mechanism and material properties of Umka landslide were well defined by previous geotechnical investigations (Ćorić et al. 2016; Abolmasov et al. 2012). This landslide is fan-shaped, with the length along the slope of 900 m, 1650 m wide in the toe, reaching maximum depth of sliding surface at 26 m, and average slope gradient of 9°. Previous geotechnical research has shown that Umka landslide can be described as complex landslide within the stiff fissured Miocene (M_3^2) clayey marls. Landslide is active, with various phases of deceleration and acceleration, which are mostly in correlation with the Sava river level rise/drawdown, respectively, whereas landslide velocity is characterized as slow to very slow (Abolmasov et al. 2015).

Methods

In the past decades many authors integrated monitoring data from different sources to reduce uncertainities. Monitoring activities are composed of several techniques introduced for landslide monitoring: automated GNSS monitorong network, geodetic benchmark survey monitoring, UAV imaging with photogrammetric processing and analysis, and PSInSAR data processing and analysis. Common to all implemented monitoring techniques is to measure displacement of the observed points (*dx*, *dy*, *dz*) on the landslide surface. Results of all monitoring activities were analyzed according to the longest common survey period and then used for cross-correlation and for verification of monitoring results obtained using different techniques.

Results

Displacement rates from GNSS indicate that object point Umka GNSS has moved 0.30 m towards the North and 0.50 m towards the West, while the vertical displacement was approximately -0.15 m for the 2014-2018 time span. Similar range of GNSS displacement rates were found in previously published results from GNSS monitoring activities realized from 2010-2014 (Abolmasov et al. 2015). PSInSAR data analysis showed very good correlation between nearest PS points and GNSS point for the same period of monitoring (2016-2018). Results from geodetic survey benchmarks (conventional monitoring) showed displacement rates in accordance to average displacement rates of GNSS object point. Results from UAV and geodetic benchmarks survey data analysis showed also very good correlation in vectors azimuth (for the period 2018-2019) (Figure 1).

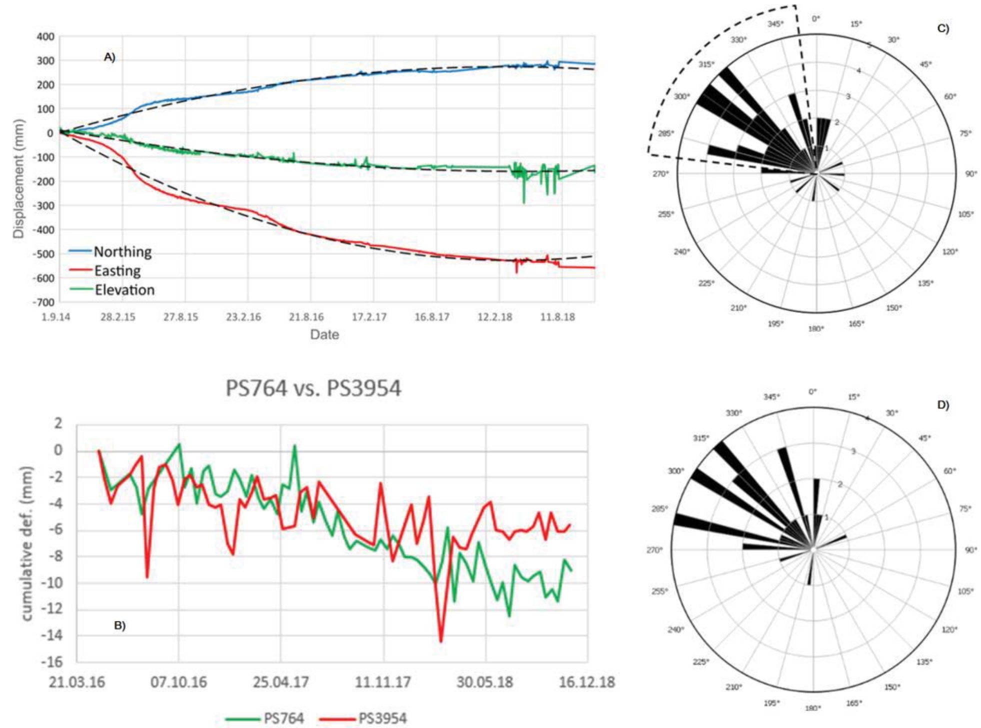

Figure 1. A) GNSS monitoring data (2014-2018); B) PSInSAR monitoring data (2016-2019); Displacement vectors azimuth obtained from C) Geodetic benchmarks survey (2018-2019) and D) UAV imaging (2018-2019)

Conclusion

Compreshesive monitoring activities on the Umka landslide included several landslide monitoring techniques realized from 2014 to 2019. According to the analyzed data it could be concluded that all monitoring results are in compliance with previous published research and monitoring results, and confirm that the Umka is a slow to very slow moving landslide.

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