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3Д ТЕРЕСТИЧКО ЛАСЕРСКО СКЕНИРАЊЕ И ГПС ТЕХНОЛОГИЈА ПРИ ИСТРАЖУВАЊЕ НА СТАБИЛНОСТА НА КОСИНИ - ПРИМЕРИ

Б. Аболмасов[1], *Св. Миленковиќ*[2], *А. Ристиќ*[3], *Г. Хаџи-Никовиќ*[4], *У. Ѓуриќ*[5]

Резиме

Како резултат на брзиот развој и примена на новите технологии кај свлечишта и косини во цврсти карпи, започна и еволуцијата на опремата за картирање и мониторинг на теренот. Технолошката еволуција на ЛИДАР (Light Detection and Ranging) системот создаде голем потенцијал за автоматско далечинско собирање на прецизни податоци со висока резолуција и претставува чекор напред кој ќе ја зголеми брзината, прецизноста, финансиската ефектност и комплетниот квалитет на геотехничките истражувања. Овој труд ги претставува карактеристиките и предностите од воведувањето на нов пристап кој ќе овозможи добивање на квалитетни планови кои се база за детални геотехнички истражувања.

Клучни зборови

ЛИДАР, податоци со висока резолуција, стабилност на наклони, геотехнички истражувања

3D TERRESTRIAL LASER SCANNING AND GPS TECHNOLOGY FOR SLOPE STABILITY INVESTIGATIONS - CASE STUDIES

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Summary

As the rapid adoption of new technologies for landslide and rock slope engineering continues - the natural evolution of equipement for landslide mapping and monitoring has started. The technological evolution of LIDAR (Light Detection And Ranging) system creates the potential for automated remote collection of accurate, high resolution data and represents step foreward that will increase speed, precision, cost effectivenes and overall quality of geotechnical investigations. This paper presents features and benefits of introducing relatively new approach in order to provide quality plans as a base for detailed geotechnical investigations.

Key words

LIDAR, high resolution data, slope stability, geotechnical investigations

1. INTRODUCTION

Detailed geotechnical investigations of slope stability in the most cases require precise surveying base, as one of the preconditions for the precise presentation of geometry and position of instability in space. Standard methods of site surveying provide satisfactory results in the most cases; however, practice often proves that higher precision, i.e. larger number of surveyed points in the state coordinate system is required for the design of rehabilitation measures. In addition, collection of data on the site causes many difficulties, since the estimation of slope stability of infrastructural construction in the hard rock masses, i.e. and presentation of data on discontinuances on topographic base i.e. vertical section of site is in subject. The possibility of monitoring of the potentially unstable areas with monitoring of stability state in time by conventional surveying measurement methods is long-lasting and exhausting process.

3D laser scanning is a system that scans real objects to produce three dimensional discretely sampled surface which represents those objects. The spatial information data are stored as or can be transformed to be stored as a group of x, y and z coordinates. New technology of surveying by LIDAR enables automatic and fast collection, processing and storing of large number of data. The data of spatial information can be exported to computer-aided design applications for additional modeling such as AutoCad, or as a 3D Digital Terrain Model.

In this paper we present two case studies of scanning by 3D Terrestrial Laser Scanner. The case studies presented ilustrate the effect of topographic surface characterization by 3D LIDAR and possible application in geotechnical investigations of slope stability.

2. MEASUREMENT METHOD AND SITES LOCATION

2.1. LIDAR Survey

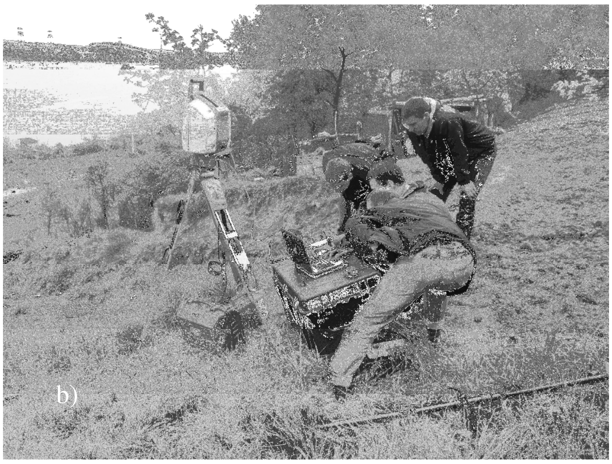
LIDAR (Light Detection And Ranging) is a optical remote sensing system that measures properties of scattered light to find a range and/or other information of a distant target. The prevalent method to determine distance to an object surface is to use laser pulses. The range to an object is determinated by measuring the time delay between transmission of a pulse and detection of the reflected signal. There are several basic components to a LIDAR system: Laser, Scanner and optics, Photodetector and receiver electronics and Position systems (GPS-Global Positioning System).

Generally, there are two possibilities for three dimensional mapping technology related to geotechnical engineering and slope stability problems - measurements made from airborne LIDAR (from airplanes or helicopters) or ground-based terrestrial LIDAR. The application of airborne LIDAR for slope stability assessment disscused in [4], [7] and [8]. Terrestrial LIDAR measurements have been used for several slope and rock cuts stability assessment as disscused in [1], [2], [5], [9, 10], [12].

In the examples in the paper, one performed 3D laser scanning of terrain surface by Terrestrial 3D LIDAR (3D TLS). The specific feature of terrestrial laser scanning technology is that it automatically registers “point cloud” on the basis of the given scanning resolution instead of standard surveying measurements of the points which requires procedures of visioning and repetitions. The used model of scanner has also a camera which adds the value of registered electromagnetic radiation in the visible part of spectre to each scanned point, i.e. pixel RGB (red, green, blue) value. After scanning, the filtration of point cloud is performed by adequate algorithms to remove murmurs in the sample of collected data. The last phase is modelling of 3D Digital Terrain Model on the basis of assembly of points by suitable software tools.

2.2. Sites location

Both examples of scanning by 3D TLS were performed by Leica ScanStation2 (Figure 1a and 1b). Technical features of the device are available at www.leica-geosystems.com.



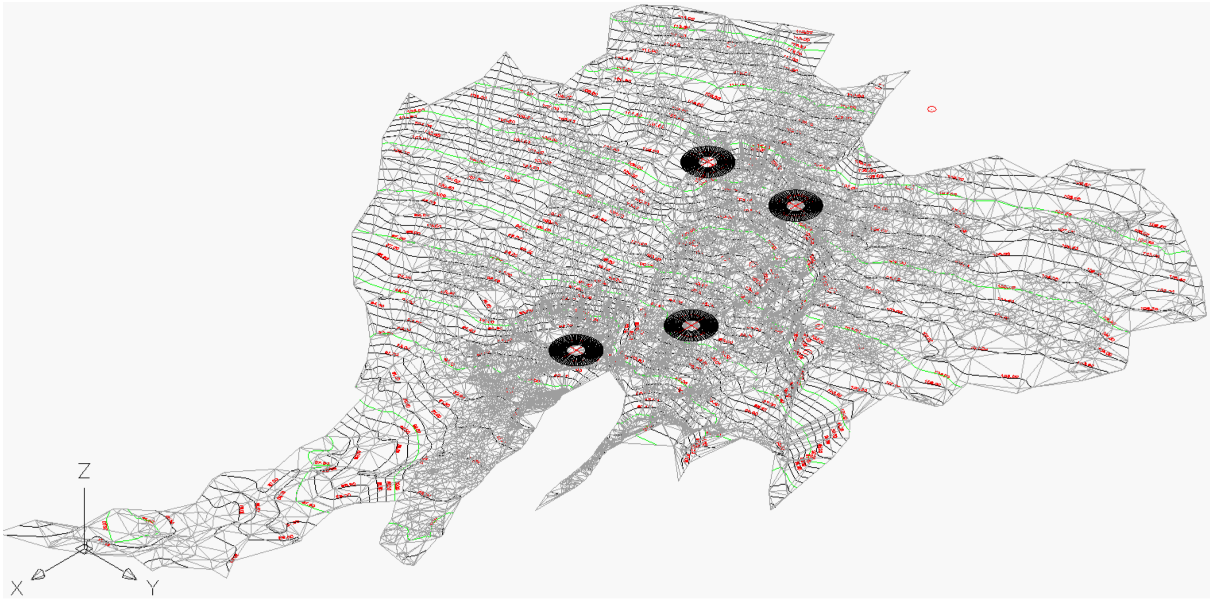
Слика 1 Примена на Leica ScanStation2: а) карпеста косина „Летња позорница“; б) свлечиште Винча

Figure 1 Leica ScanStation2 on both examples a)“Letnja pozornica“rock slope and b)“Vinča“ landslide

The first example of TLS application refers to location of active landslide near Belgrade, in the village Vinča on the right bank Danube. Landslide was formed by Neogene sediments in the contact of thin layer of degraded and weathered marly clays. The landslide moved also the roof of Neogene sands and loess Quaternary sediments. The landslide is shallow, of small volume and area, however, its activity jeopardizes three private resident houses. Reactivation of landslide is directly connected to the rainfall regime, since the recent monitoring of its activity showed the movement inside the landslide body or progressive increase of its volume moving along the slope after large rainfalls. The first 3D laser scanning was performed in July 2009 and the second one in the April 2010. The reactivation of landslide occurred in January 2010 in the period between these two scanning.

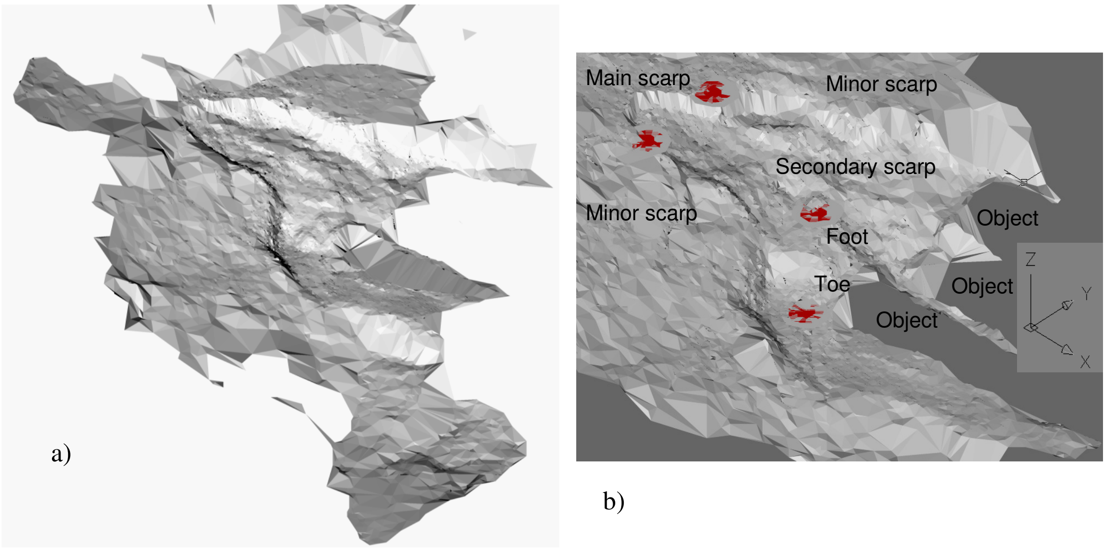
After the first scanning, the creation of site surface model in the wider zone of landslide and landslide zone itself was performed on the basis of the procession of collected data obtained by acquisition by Leica ScanStation 2, terrestrial laser scanner, with resolution of scanning of 10 cm/10m. The “point cloud” was formed by scanning from 4 different positions of scanner which included area ~ 570 m^2 of the landslide and surrounding zones. During the formation of Digital terrain Model (DTM), the procession of data on the basis of elimination of measurement errors and classification of points according to belonging to the terrain, buildings or trees was performed. Thus obtained DTM, model of terrain surface was used for geo referencing of data of basic morphological elements of landslide. The calculation of moved material according to the method described under [6] was also made. Results of analyses DTM [6] showed the quantity of moved material amounts to 1850 m^3. The Figure 2 presents DTM in the form of contours lines and with marked position of laser scanner during acquisition. The Figure 3b also shows the landslide with marked basic elements after the first scanning in the form of triangles and 3D DTM.

The procedure was repeated during the second scanning and the obtained 3D model of terrain is presented on the Figure 3a. The alternation of morphometry of landslide body can be clearly seen on figures, i.e. the amount of secondary movement inside the landslide body as well as alternations in the zone of left lateral scarp (Figure 3a and 3b).



Слика 2 Дигитален модел на теренот за свлечиште со позиција на ТЛС од јули 2009

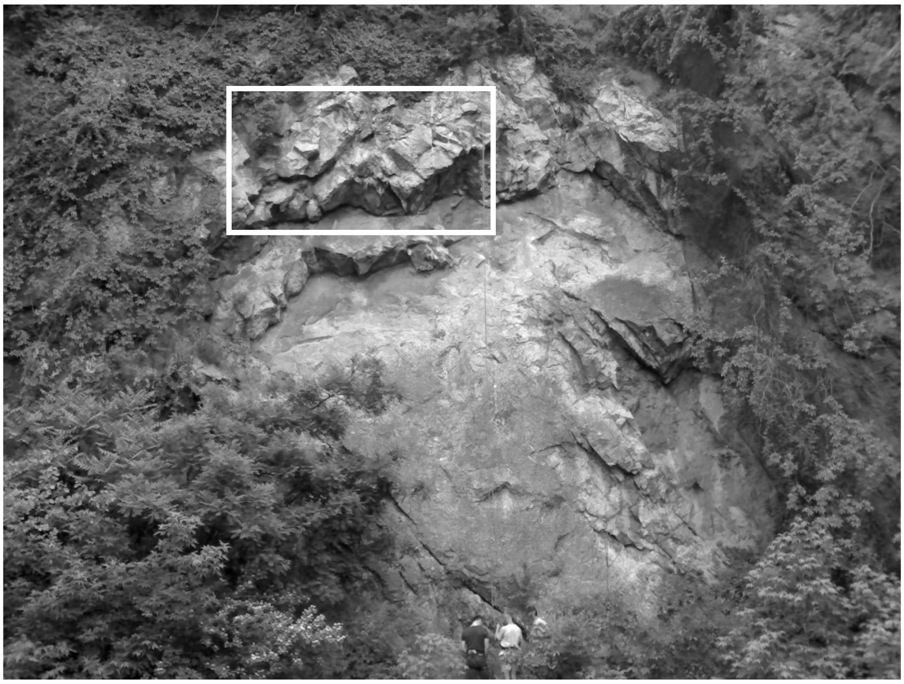
Figure 2 Digital Terrain Model of landslide with the position of TLS from July 2009



Слика 3 3Д Дигитален модел на теренот за свлечиште од април 2010 (а) и јули 2009 (б)

Figure 3 3D Digital Terrain Model of landslide from April 2010 (a) and July 2009 (b)

The second example refers to the slope on the location of "Letnja Pozornica" in Belgrade in the area of protected natural-geological heritage. The space at the location was used as natural theatre scene during the nineties, but nowadays it is totally deserted. The small rock falls at t the location are obvious and due to the abandonment the protection is totally out of function. The protective nets are unfixed, torn and in the case of rock falling of volume larger that 1 m^3 they do not have any protective function. Terrain was formed of flysch of the upper Cretaceous with a lot of fossil residues, and due to it the whole location is protected as natural-geological heritage. Slop is nearly 20 m high, with orientation 10/75 and inaccessible for direct measurement of joint parameters (Figures 1a and 4).



Слика 4 Карпеста косина „Летња позорница“ со означен детаљ (бел правоаголник)

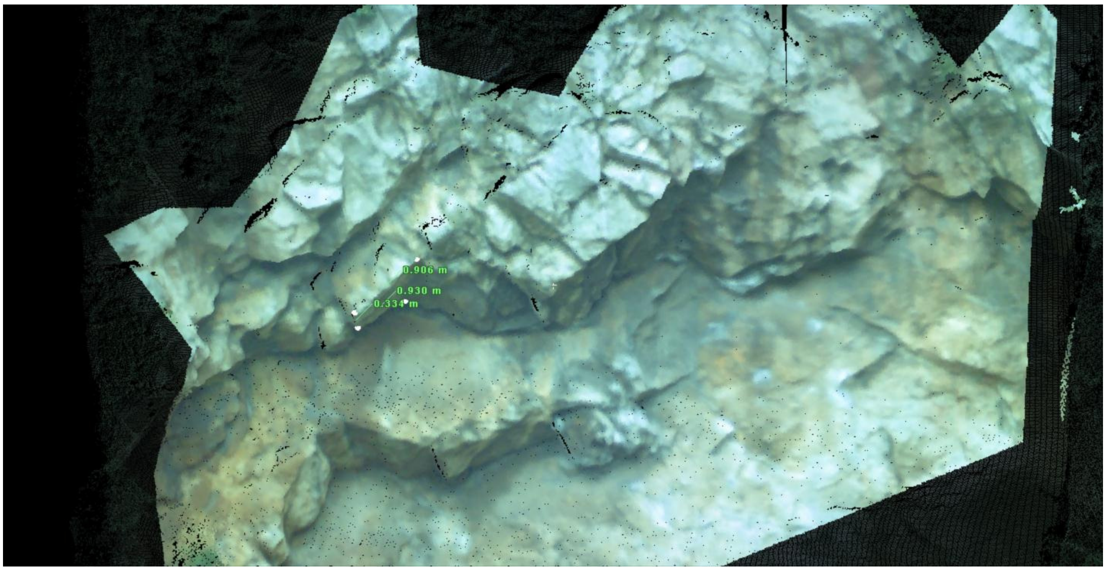
Figure 4 “Letnja pozornica” rock slope with marked detail (white box)

The process of scanning was performed by Leica ScanStation2 as in the previous example, but the 3 scans were performed with different resolutions. The first scan was carried out with resolution 5cm/30m, the second on 1 cm/30m and the third one with resolution 0.5cm/ on 15 m. The “point cloud” obtained by scanning with 5cm resolution of zoomed slope detail is presented on the Figure 5 while Figure 6 shows the same zoomed slope detail with resolution 1 cm where in the both cases the RGB value was added to each point.

Слика 5 Точкаст облак со РГБ и резолуција од 5 см

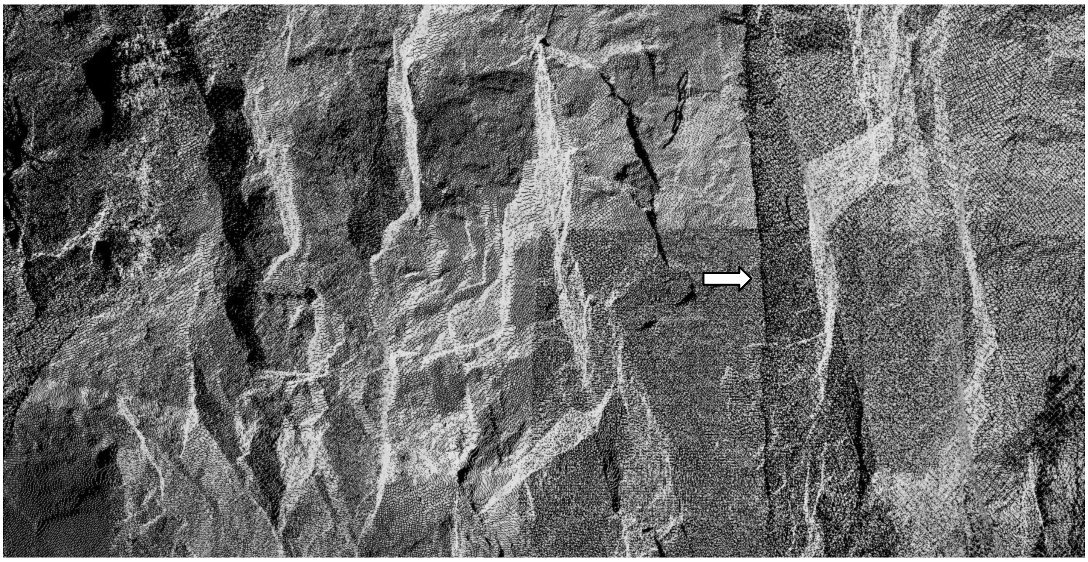
Figure 5 Point cloud with RGB and resolution on 5 cm

The Figure 7 shows point cloud of slope detail (on gray scale) with resolution 0.5 cm on the SE part of slope.



Слика 6 Точкаст облак со РГБ и резолуција од 1 см

Figure 6 Point cloud with RGB and resolution on 1 cm



Слика 7 Точкаст облак (сивосенчен) со резолуција од 0.5 cm и стара скината заштитна мрежа (бела стрелка)

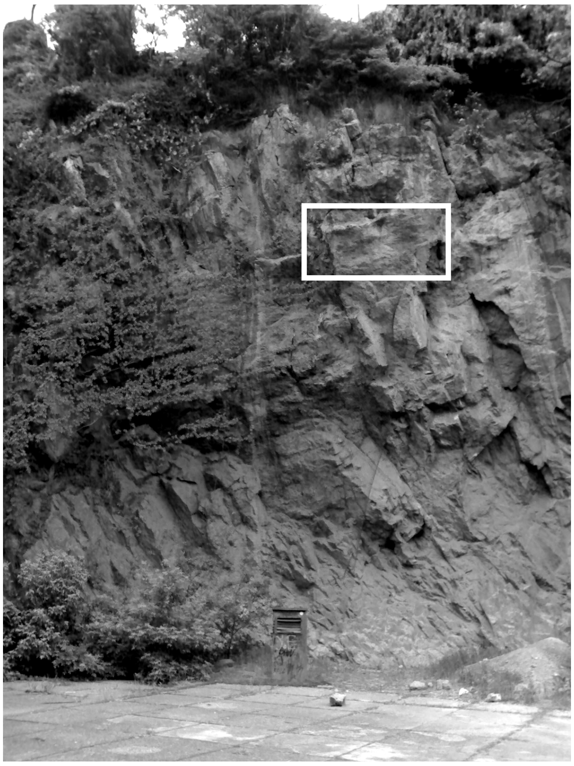
Figure 7 Point cloud (gray scale) with resolution on 0.5 cm and old torn protective net (white arrow)

3. RESULTS AND DISSCUSION

The basic idea of 3D terrestrial laser surveying on both locations is to detect possibilities of application of relatively new technology of site surface surveying, i.e. its application in the future geotechnical investigations of slope stability.

Surveying performed at the location of landslide in Vinča provided topographic base for the short period of surveying where the interpolation of the points was carried out in the domain of precision of 10 cm. Each point in the point cloud is referenced in the state coordinate system, i.e. has the value x, y, z. The topographic base is made as the outcome where the relief of terrain is presented in the couture lines and 3D DTM in two time series. The number of surveyed points, the precision of topographic base obtained in such way, as well as the speed of surveying is incomparable to the conventional method. In addition, the monitoring of alternation of landslide body volume in the two phases of activity with the real movements of points in the coordinate system is also enabled. It should be mentioned that no topographic base in the scale larger than 1:2000 from 80-is, i.e. the last survey in scale 1:5000 existed on the location of landslide and its wider surrounding.

Surveys performed on the location “Letnja pozornica“ aimed at determination of possibility of obtaining precise topographic base of natural slope in the hard rock, which is the often problem in the detailed mapping for slope stability and the conditions of their maintaining. Taking into consideration the height and grade of slope, the problem of mapping of inaccessible parts of slope existed, i.e. the issue of possible errors during presentation of joints line by conventionally surveyed slopes. The first performed scan with resolution on 5 cm provided “point cloud” with satisfactory precision referring the precision of base for the requirements of detailed mapping of slopes. We would like to mention that the scanning for the slope 20 m high and 40 m long lasted 10 minutes with previous geo referencing which lasted 20 minutes. No additional referencing was required for any further scanning. However, better visualization and possibility to perform further detailed mapping of joints was achieved by further scanning with resolution 1cm, i.e. 0.5 cm of slope detail (Figure 6 and 7). Both figures present slope details which are inaccessible for direct measurement of jointing features (Figures 4 and 8). In addition to details of surveyed base and visualization of real state on terrain the details of torn protective net are also presented in the left and right corner on the Figure 7. Beside the point cloud presented at Figures 5, 6, and 7 obtained by scanning in different resolutions, the base in AutoCad® was obtained as an outcome, which satisfied the need for preparation of vertical sections of terrain, where each point in the section was referenced in the state coordinate system.



Слика 8 Карпеста косина „Летња позорница“ со означен детаљ (бел правоаголник) (резолуција 0.5 cm)

Figure 8 “Letnja pozornica” rock slope with marked detail (white box) (resolution 0.5 cm)

After scanning of terrain on both locations, the advantages of obtained topographic bases with 3D terrestrial LIDAR, showed numerous additional possibilities in addition to the application of the bases as the background for performance of remedial measures. The exact amounts of movement in the different phases of activity can be obtained during landslide investigations, which can provide clear picture on the parameters of process dynamics in the case of active landslide with the cycles of reactivation [13]. Series of surveying can also provide exact volumes and precise located of fallen material in the hard rocks where the rock falls are dominant [14].

4. CONCLUSION

The results of performed investigations, i.e. scanning of terrain indicated the numerous possibilities of applied technologies, which can be briefly summarized in the following advantages. The speed of measurement and automatic processing of data provide topographic base in every short period with the precision which can be adapted to each concrete case but in any case it is more precise than any conventional method of surveying measurement. The possibility of export to numerous user program which are used for the presentation of design documentation, enables application of data in the geotechnical practice. The advantages of remote sensing approach enables the obtaining of data of higher precision in the case of inaccessible slopes (very high slopes or vertical ones), where the data on joints can be obtained only by visualization. Preparation of Digital Terrain Model enables additional modeling which can help designer to see the problems of instability more easily for example along the lines of infrastructural constructions. The economic advantage of this method is indisputable due to the quality of data obtained in a short period and the possibility of work in all conditions.

3D terrestrial laser scanning of terrain on these two locations was performed for the first time in Serbia aiming at determination of possibility of its application in the detailed geotechnical investigations of slope instability. Additional investigations which would connect monitoring of landslide activity or possibility of connection of data of scanning, detailed mapping of joints with adequate software for calculation stability are impending.

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