DOCUMENTATION AND PRESENTATION OF VERY STEEP AND ROCKY GROUND SURFACES BY GEODETIC METHODS.

Dennis D. Balodimos, Evangelia Lambrou and George Pantazis

National Technical University of Athens
School of Rural and Surveying Engineering
Department of Topography, Laboratory of General Geodesy
9 Herron Polytechniou, Zografos, P.O Box 15780, Athens, Greece.

Abstract

This paper deals with a Geodetic method for fast and accurate Surveying and Mapping of very steep and rocky ground surfaces. A review of the existing methods and instrumentation is given while the investigation concerning the instrumentation is focused on modern Total Stations that may function without reflectors and allow for the fast and accurate positioning of inaccessible points in a local 3d reference frame. Emphasis is given to the optimal presentation of the results (mapping) in order to allow for easy access to other Geoscientists that have to carry out any kind of work on the site. The method was applied for the Surveying and Mapping of a very steep rocky ground surface of the Mythimna fortress on the island of Lesvos, where there is a need for supporting works in order to prevent the fall of rocks.

1.Introduction

The study of the stability behavior of the earth's crust is, today, one of the most important research topics for engineers, as it is strongly correlated with the procedure that should be followed for the conservation of existing natural or manmade structures as well as for the correct planning of new ones (buildings, bridges, roads etc.). This study being rather complicated requires the collaboration of scientists from different disciplines.
The monitoring of the kinematical behavior of any part of the earth's crust and the registering of damages observed over time, consist the most important information for the planning of the works needed for the protection of the existing structures.
The process begins with the surveying of the area and the documentation of existing damages.
Steep and rocky ground surfaces consist of parts of the earth's crust created by geological changes over many hundreds of years or by technical interventions. Such sites were usually chosen during the Middle ages for the construction of fortresses to protect the towns from invaders. In Greece such geological formations exist in several places such as Meteora, Molyvos, Monemvasia etc.
Surveyors, today due to the rapid evolution of technology can contribute strongly to the geometric documentation, registering and monitoring of steep, rocky and inaccessible declivities, by Geodetic, or Photogrammetric methods or by exploiting the Scanning technology.

2. Procedure

2.1. Framework and scale

In order to achieve the geometric documentation of a rocky and steep declivity one should define its position, shape, magnitude and all the existing details in a 3-d reference frame. This

process leads to the production of accurate plans, in the appropriate scales, to be used for the planning of the necessary interventions for the conservation and support of the surfaces. The plans that may be produced are a general plan of the area, plans of horizontal sections at different heights, plans of vertical section and facades, rectified photographs or orthophotomaps. The choice of the appropriate scale, for the plans is very important and depends on the following factors:
- The geometric characteristics of the declivity (height, length, unfolding)
- The relief of the outer - area of the declivity.
- Special characteristics that must appear in the plans.

The scales usually chosen for the general plans are 1: 500 or 1:200 and rarely 1:100. While 1:200 or 1:100 are considered more appropriate for vertical sections and facades.
For the surveying of a declivity, a 3d network has to be established. This network should be developed in the outer - area and its points, which will be used as reference stations for the determination of all the detail points needed for the production of the plans, should be realized by permanent marks. The elements of the network may be measured by terrestrial or satellite geodetic methods.
After the appropriate reductions and adjustment of the measurements, the coordinates of all the points, in a 3-d reference frame may be computed.

2.2 Geodetic Methods

The detailed survey of rocky ground surfaces presents difficulties mainly because of the fact that they are inaccessibility. As the detail points of the declivities are usually inaccessible classical geodetic total stations cannot be easily used. Thus, the surveying may be carried out either by simultaneous angle measurements (resection) or nowadays using reflectorless total stations.
The method of resection requires simultaneous sightings to each detail point, from two different stations and horizontal and a vertical angle measurements from both stations. For the application of this method there is no need for distance measurements but the following are necessary:
- The realization of the detail points of the declivity from a distance away, which is usually done using a laser pointer system.
- The existence of a dense and appropriately designed 3d network.

This method is both time consuming and cumbersome with an accuracy of a few cm, depending on the accuracy of the angle measurements and the geometry of the triangle formed each time between the target point and the two stations.
Due to the evolution of geodetic instruments to modern total stations, which allow for the measurement of horizontal and vertical angles as well as distances without reflectors or special targets, it is possible to determine accurately the coordinates of inaccessible points in a fast and easy way.
These instruments, which vary according to their accuracy and range, have the ability to realize the target point on site, on any kind of surface, by a laser pointing system and measuring the respective distance. The first generation of such instruments could emit a very strong laser beam and measure distances up to 80m with an accuracy of ± 5mm. These instruments mounted on digital theodolites function as total station, with the disadvantages of not being homoaxial with the theodolite. Later on reflectorless total station that can measure distances up to 200m with an accuracy of ±3mm were developed while the most modern instruments can measure distances from 2m to 600m with accuracies between ± 3mm to ± 5cm according to the distances. The accuracies of the coordinates are of the same order of magnitude as the accuracy of the distances.
It is also possible to carry out the 3-d survey of a declivity using total stations that can sweep the surface automatically as long as an horizontal and a vertical sweeping-step is set. The advantage in this case is that observations are carried out without the interference of the observer and thus, a great number of points can be determined quickly, easily and independently from the uncertainty of the point sighting (Trimble, 2002).

2.3 Photogrammetric Methods

For the recording of vertical declivities terrestrial or aerial photogrammetric methods may also be used. In this case the products are usually orthophotomaps and plans of sections and facades produced from stereoscopic restitution of metric photographs.
The terrestrial photography methods may be applied when the distance between the point where the photograph is taken and the declivity, is long enough to allow for the taking of the photograph.
For the application of terrestrial photogrammetry the following are required:
- A number of control points on the declivity surface to be used for the appropriate reductions of the photographs. If, due to the inaccessibility of the declivity, it is not possible to establish such points, characteristic points of the surface, clearly appearing on the photographs, may de used.
- The geodetic determination of the coordinates of the control points.
- The proper planning of the photograph shots, especially in the case that they are to be used as stereoscopic pairs.
- The use of special metric cameras and negatives formats. (102×127 mm^2 or 89×119 mm^2 or 13×18 cm^2) was according to the magnitude of the object.

The accuracy of the plans, which is of the order of ±10 cm, depends on the shape and the relief of the declivity, on the scale of the photographs, the percentage of covering of the stereoscopic pair and also on the accuracy of the coordinates of the control points (Kraus, 1991).
Aerial photogrammetry may be applied using a helicopter or a balloon and a metric camera but it is more expensive and complicated.

2.4 Laser Scanning

Laser Scanners are very recently developed instruments that can scan a large area producing 3d digital plans with out the requirement of presetting horizontal and vertical steps as it happens with total stations mentioned in 2.2.
These instruments can measure about 1000 to 10000 points per second as a cloud of points. In addition using appropriate software it is possible to produce a 3d-digital plan of the scanning area during the measurements. The measurement range of these instruments varies from 1.5m to 100m and the coordinates of the points may be determined with an accuracy of ±6mm to ±45mm (Pellegrinelli, et al, 2001) which is satisfactory for the 1:100 scale and depends on the following parameters:
- The distance from the object
- The scanning speed
- The nature of the reflecting surface
- The method of the laser ranging system that each one use.

Some of the disadvantages of these instruments are
- Their slow speed of scanning and the short-range ability.
- Their weight which ranges from 10Kgr to 30Kgr
- Their high cost
- The size of the laser spot that comes out has a diameter of 15mm to 300mm for distances up to 50m, so it becomes difficult to resolve small objects.
- Their field of view that is limited, especially in the vertical direction, which means that their distance from the scanned surface should be long in the cases of very steep any height surfaces.

Another problem is the interference of "unwanted" data, recorded within the cloud of points (Johansson, 2002).
As concluded from the above mentioned, laser scanners may not be considered yet as the ideal instruments for cases that can be carried out by Geodetic or Photogrammetric procedures.

2.5 Choice of the appropriate method

The choice of the appropriate method for each case depends on:
-The magnitude of the surface to be surveyed.

-The accessibility for the establishment of permanent control points
-The position of the surface in relation to the surrounding area. If there is not enough distance between the surface and the camera, terrestrial Photogrammetry is not applicable.
In table 1 the characteristics of the methods described in the previous paragraphs are depicted.

Method		Accuracy	Time – Cost	Products
Geodetic	*Resection*	± 50mm	Time consuming – high cost	Plans of horizontal and vertical sections - facades
	Use of Reflectorless Total Stations	±3mm – ± 50mm	Quick – Low cost	Plans of horizontal and vertical sections - facades
Photogrammetric	*Terrestrial Photogrammetry*	±20mm – ± 100mm	Time consuming Low cost	Plans of horizontal and vertical sections – facades
	Aerial Photogrammetry	±100mm	Cumbersome Quick in the office High cost	Orthophotomaps. Plans of horizontal and vertical sections – facades
Other	*Laser Scanning*	±6mm – 45mm	Not determined yet High cost	Plans of facades

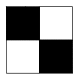
Table 1. Characteristics of the Methods

3. Case study

The present case refers to the production of the appropriate plans of the rocky and steep declivity at the South section of the Mythimna fortress, on the island of Lesvos (fot.1) in order

Fot.1. The fortress of Mythimna

to assist the Geotechnical study for the supporting of the rocks.(Project ″Surveying of the rocky declivities of the Mythimna fortress″, NTUA, Prof. P. Marinos).
The position of this vertical declivity with respect to the inhabited area did not permit the application of terrestrial photogrammetry. The rocky declivity is almost tangent to the inhabited area of Mythimna and has a height of about 35m.
Thus, due to the fact that the surface was not easily accessible (very steep and rocky) the most appropriate method for its surveying appeared to be the one using a Total Station without reflectors.
Initially a 3-d geodetic network consisting of nine stations was established in the surrounding area. The measurements of the elements of the network were carried out by a modified method of the ″three tripods″ (Balodimos, 1996), in order to eliminate all the leveling and centering errors of the instrument. Horizontal and vertical angles were measured as well as the distances between the points. The network was adjusted at an arbitrary reference system with the Y-axis roughly directed to the North. The coordinates of the network stations were computed with an accuracy of ±1 cm (Balodimos, et al, 2001).
The particularity of the project dictated the establishment of 27 permanent control points on the surface, which consisted of special self-adhesive 5cmx5cm aluminum targets stuck on the rocks (fot. 2). These points, whose position is depicted in all the plans, were useful for the controlling of the plans, and are expected to assist scientists and contractors in the future stages of the project.



Fot.2. The aluminium target point

The total station Leica TCR303 was used for most of the measurements. This total station measures distances up to 100m without reflector with an accuracy of ±3mm ±2ppm and angles with an accuracy of 9^{cc} (Leica Heerbrugg AG, 2000). Points observed on the fortress of Mythimna were:
-All the specific points needed for the drawing of the plans.
-The 27 aluminum target-points.

Figure 1. The plan of the rocky ground surface of the Mythimna fortress.

-Points, on the chopped trees' trunks existing on the declivity.
-Points, on the borders of specific rocks and cracks.
Appropriate software was used for all the computations and drawings.
The plans produced are the following:
-A 1:100 plan of part of the fortress, the rocky declivity, and the inhabited area around the fortress.
- A 1:100 plan of the facade of the declivity
- Four 1:100 plans of horizontal sections of the same area, at the heights of 20m, 25m, 28m and 31m relative to a conventional altimetric reference point.
- Five plans of vertical sections at specific positions.
Figures 1,2 and 3 consist samples of the produced plans.

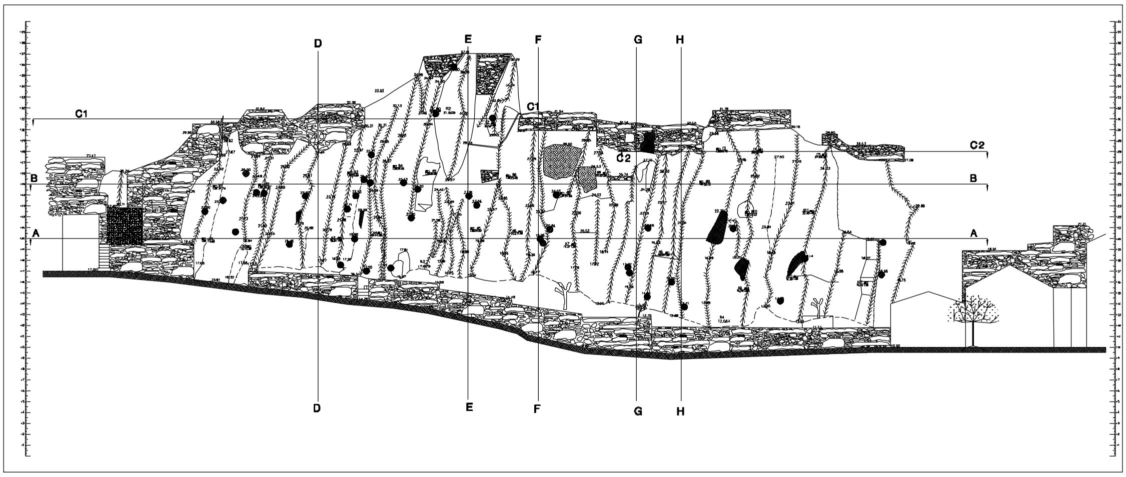


Fig.2. The facade of the rocky ground surface of the Mythimna fortress.

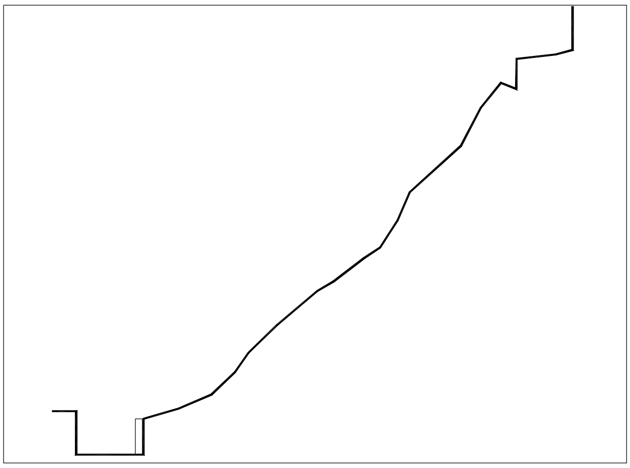


Figure 3. The vertical section E - E.

The Leica TCR303 Total Station did not function properly in some observations to inaccessible points on the declivity. The problems were the following:
-Inability to measure some distances. This was due either to the poor reflect ability of the surface or to the poor geometry between the station and the point observed.
-Difficulty to realize some inaccessible points due to the power of the emitted laser beam.
These problems were overcome using the older technology instrument Leica DIOR 3002 mounted on the digital Theodolite Leica T1610. Although this system is not homoaxial, requiring thus a geometrical reduction, it functions properly as the DIOR3002 has a strong laser

beam with a narrow diameter, which facilitates the observations in the cases where TCR303 can not be used.

5.Conclusions

The Geodetic method using digital total stations without reflectors proved to be efficient for the reliable documentation of very steep and rocky surfaces. The general plan and the plans of the vertical and horizontal sections produced, provide full geometric information for all the elements (rocks foot, peak and crevices) that compose the relief as well as for all the constructions existing in the surrounding area.
The main characteristics of the geodetic method as applied in this project are:

a) The convenience and speed of the measurements.
b) The accuracy of a few centimeters achieved.
c) The low cost of the whole Topographic campaign.

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