

# **MONITORING OF SHORE CLIFF WITH THE APPLICATION OF SCANNING INSTRUMENTS**

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## **1. INTRODUCTION**

The coastline in Poland is around 500 km long, including around 110 km of shore cliff (Szopowski, 1961). These usually have a relatively narrow beach and steep slope with clear undercut of the base resulting from abrasion. Cliffs belong to the most interesting types of sea coast, and enjoy a great interest on the part of scientists dealing with their protection, geological structure, and monitoring.

Up to this time, the geodetic surveys of shore cliff have been conducted by means of classical methods, namely establishing the location of top edge and the bottom of the cliff slope. Such observation is not sufficient to monitor detailed changes taking place on the shore cliff. Application of ground photogrammetry to examine cliff retreat proves difficult because of narrow beach. Aerial photography can be unsuitable due to long vertical sections of a cliff or tree branches protruding over cliffs.

A number of years ago, first reflectorless tacheometers became available, enabling direct surveying of undesignated points (Rzonca, 2004). During subsequent years, these instruments were equipped with servo motors and software, thus creating a new subtype – scanning tacheometers. Over the last few years, ground laser scanners, one of the major technological achievements in geodesy, developed significantly. Application of these instruments throws new light on cliff shore monitoring. Reflectorless technology allows safe surveying of a cliff slope, which can oftentimes be difficult to access.

The article presents the application of scanning technology in shore cliff monitoring. Such surveys have not been conducted in Poland so far. Abroad, experimental surveys, with the use of ground laser scanning, regarding damage of coastline have been carried out by e.g. Jean Instrument Company and Baltic Aerogeodetic Company in the Kaliningrad District (Skanowanie laserowe ... 2008) as well as the British Geological Survey on the southern shore of the British Isles. (Pennington and Hobbs 2008).

## **2. OBJECT OF STUDY**

The object of study is a section of shore cliff situated on the Baltic Sea in the vicinity of Pleśnia village, between 314 and 315 km of the coastline, according to the Polish coastline kilometric marking (fig. 1). The beginning of the Polish coastline is located on the Polish-Russian border on the spit of Vistula Lagoon, while its end is marked on the

428 km, on the Uznam Island on the Polish-German border (Szopowski, 1961). The examined cliff is 150 m long and 5 to 10 m high. This object is located in the area of water waves activity. It was decided to conduct the surveying of this particular object, because dynamic changes taking place on this cliff were observed.

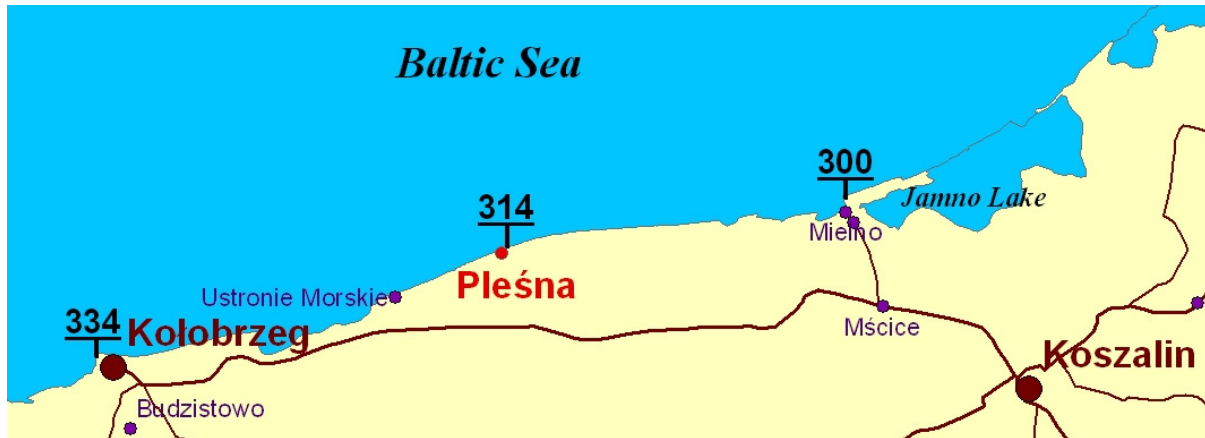


Fig. 1. Location of the object of study.

### 3. INVENTARIZATION WITH SCANNING TACHEOMETERS

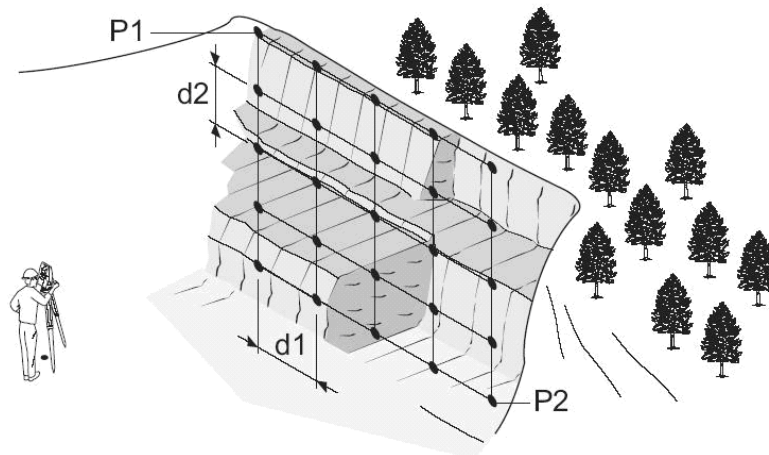
The most significant damage of sea shore takes place in the autumn and winter. Most storms occur in this period. Therefore, it is best to conduct the survey after this time, and right before the plants flourish, which could hinder observation. The inventory survey of the cliff was conducted in April 2006 with Topcon GPT-8203A SCAN robotic tacheometer, belonging to a group of scanning tacheometers (fig. 2a). The scanning function in this station is realized by a set consisting of reflectorless EDM, servo motors, and a computer with a controlling software. The EDM allows distance measurement to any given target, not signalled by a reflector. Servo motors controlled by a computer automatically adjust the sighting axis of the telescope vertically and horizontally, according to a programmed procedure (Toś et al., 2008).

Prior to the survey, on each station, a photo was taken with a digital camera connected to the controller. Then, after orientation of the photo to at least four register marks, the scanning area was determined. After setting the horizontal and vertical interval with angular value, a program was initiated which made an automatic survey. The scanning resolution was chosen intuitively so that the survey points precisely reflected the diverse surface of the cliff. The survey, lasting around 4 hours, resulted in obtaining a set of survey points, relatively evenly distributed at the density of around 11 points/1 m<sup>2</sup> of the cliff surface. Setting a proper scanning interval and survey range is very important. Decreasing a scanning interval results in higher density of survey points, and thus prolongs the survey time, which equals around 2-4 seconds per point. Inaccurate scanning, which causes registration of useless data, outside of the monitored object, also prolongs the survey.



**Fig. 2. Tacheometers used in the survey:  
a)Topcon GPT-8203A SCAN, b)Leica TPS1200.**

The second tacheometer used in the survey was Leica TPS1200 (fig. 2b). The survey with this instrument was conducted in May 2007. It is a robotic total station, which does not belong to the group of scanning tacheometers. The producer equipped it with a surface scanning module, and thus it can be used as a typical scanning tacheometer. Prior to the survey, it is necessary to define the reference surface by appointing at least 3 points. Subsequently, the scanning range was determined through the survey of two boundary corners of the scanning surface (P1,P2), and the horizontal ( $d1$ ) and slope ( $d2$ ) size of the network were set (fig. 3).



**Fig. 3. Scanning with TPS1200 tacheometer (Source: Leica TPS1200).**

After setting the reference surface and scanning resolution, the surveying with Leica TPS1200 tacheometer was conducted automatically, just as in case of the scanning tacheometer Topcon GPT-8203A SCAN. The main difference concerned the speed of data collection. The instrument conducts the survey two or three times slower in comparison with Topcon GPT-8203A SCAN. The survey lasting around 8 hours resulted in relatively even distribution of observed points at density of around 9 points /1 m<sup>2</sup> of the surface.

#### 4. SURVEY WITH LASER SCANNER

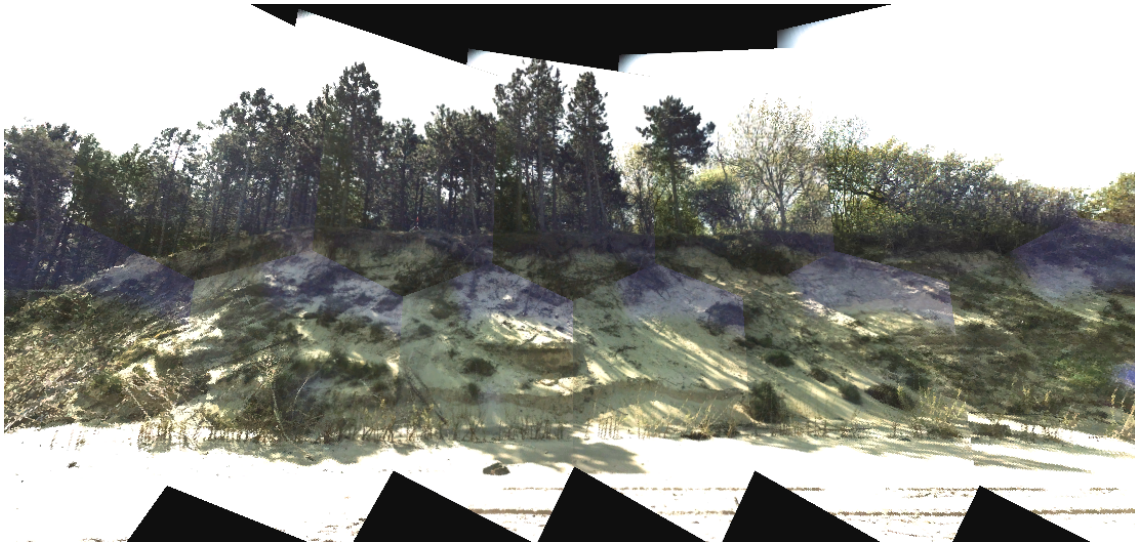
In May 2008, as a result of cooperation with the representatives of Leica Geosystem company, a HDS (High-Definition Surveying) ScanStation 2 (fig. 4) was borrowed for the purpose of the study. The instrument was used to conduct the third inventarization survey of the shore cliff damage. The scanner used in the survey is equipped with impulse laser with surveying range of up to 300 m. This instrument can obtain data with the speed of 50 thousand points/second and can save it as a cloud of points of sub millimeter resolution.



Fig. 4. Leica ScanStation 2 scanner used in the survey.

Due to a significant weight of the scanner, namely 18,5 kg and windy weather, the stations had to be carefully prepared. The legs of the tripod could not be rested directly on the sandy ground, as this would cause sinking of the instrument into the ground during the survey. Therefore, concrete tiles, size 25 25 8 cm were used under the tripod's legs and the instrument could work safely through the survey period.

The activity of ScanStation 2 scanner is controlled by an outside computer connected through Ethernet from dedicated Cyclone software. As the instrument uses only external power supply, the Honda 20i aggregate was used. Before the surveying started, a panoramic photo of the object was made with a built in digital camera at each observation station (fig. 5). The photo was used to define the surveying window, i.e. the scanning area. Moreover, the photo can be used during compilation of data, as technical documentation, or to prepare the 3D realistic visualization model (Pudlo, 2006). Another important step was setting the scanning parameters, especially the density of points i.e. vertical and horizontal resolution. The density of points should be set so that the obtained set of points precisely reflects the shape and diversity of the cliff surface and excludes redundant data. Finally, the resolution of 0,03 0,03 m vertically and horizontally was set on each station and all the visible surface of the cliff was scanned.



**Fig. 5.** Photo made by the scanner to determine the scanning range.

During the scanning process a cloud of points is registered at each station, which represents a section of the observed object. The observed points in each cloud correspond to the internal system of coordinates of the instrument, which origin is located in the centre of the scanner (Studencki, 2003; Rzonca, 2004). The clouds have to eventually be combined into one, and oriented within the outside system of coordinates (the coordinates system of the ground control network). Therefore, on each station, observation of at least three so-called common points, with defined “2000” reference system, was conducted. Finally, the cliff observation was conducted with the scanner from three stations connected to six points marked with sighting marks, which are precisely identifiable in the point cloud (fig. 6). These points were distributed evenly in the vicinity of the examined object, so that they were not collinear or coplanar. As a result of scanning and orientation of the clouds obtained from different stations, one complete cloud of points was created, representing the whole surface of the cliff, expressed in the “2000” system of coordinates.



**Fig. 6.** Example of common points signalization for different point clouds.

## 5. PRESENTATION OF SURVEY RESULTS

A cliff as a fragment of terrain is an object of a linear character i.e. present on the whole examined area. As a result of a survey it is being represented in a discrete way through a set of observed points carrying information about its shape. After application of the relevant surface modelling methods, it is possible to present it in a discrete way - as a set of algorithmically arranged grid nodes (Stateczny et al., 2004). The most often used methods of spatial surface presentation are the TIN (Triangular Irregular Network) and GRID (regular grid of squares).

The structure of GRID makes it exceptionally easy to store data and what is more, it takes up little computer memory. This method also enables easier modelling of surface in comparison with the TIN method (height interpolation at any given point, profile generation, contour lines, maps of slopes and expositions, calculating the amount of soil, easier visualization of surface in 2D and 3D configuration) (Olszewski, 2005). The GRID models can easily be subject to statistical and spatial analyses with the use of algebra map concept (MapAlgebra) proposed by dr Dan Tomalin (Tomalin, 1990). Map algebra is an advanced calculation language applied to spatial analyses with the use of raster data (Ciupa and Kisiel, 2008). This data can be perceived as matrix and mathematical and logical operations can be conducted. The GRID models are applied in case of analyses of a single object over time (Lue and Novak, 1991; Obermeyer and Pinto, 1994). One example is a shore cliff which should undergo periodic observation to register its retreat. Through the creation of differential surface from two different surveying periods, one can easily observe the changes which took place over time.

The GRID structure was chosen to build the digital model of the cliff. The Natural Neighbor method was used to interpolate the grid nodes, assuming the result resolution of 0,20 0,20 m. The cliff surface marked on fig. 8 as GRID 1 was created based on surveying data from 2006, and GRID 2 on the basis of data from 2008. Subsequently, the raster was cropped to the area on which the survey was conducted, and then the obtained cliff models were compared. The comparison was based on created differential surface. Thus, the changes taking place as a result of erosion were observed. The conducted analysis shows that the observed cliff regressed up to 3 meters over 2 years and in some places an increment in the form of colluvium was accumulated. This is typical in case of abrasion. The waves hitting the foot of the cliff create an abrasion niche, which grows in size causing loss of support and stability of the cliff. Depending on the geological structure, landslide or collapse of slope fragment thus occurs (Tejchman et al., 1995). The material in the form of colluvium lies at the bottom of the cliff supporting it until it is not washed away by the sea waves (fig. 7).



Fig. 7. Landslide caused by abrasion – Pleśna 12.05.2008 r.

The analyses did not take into consideration displacement of up to 0,2 m. Such a value can result not only from the factual changes of the cliff but also from the discrepancy between the actual and the interpolated cliff surface, which depends primarily on the density of observed points, the interpolation method applied, as well as the terrain type and its morphological features.

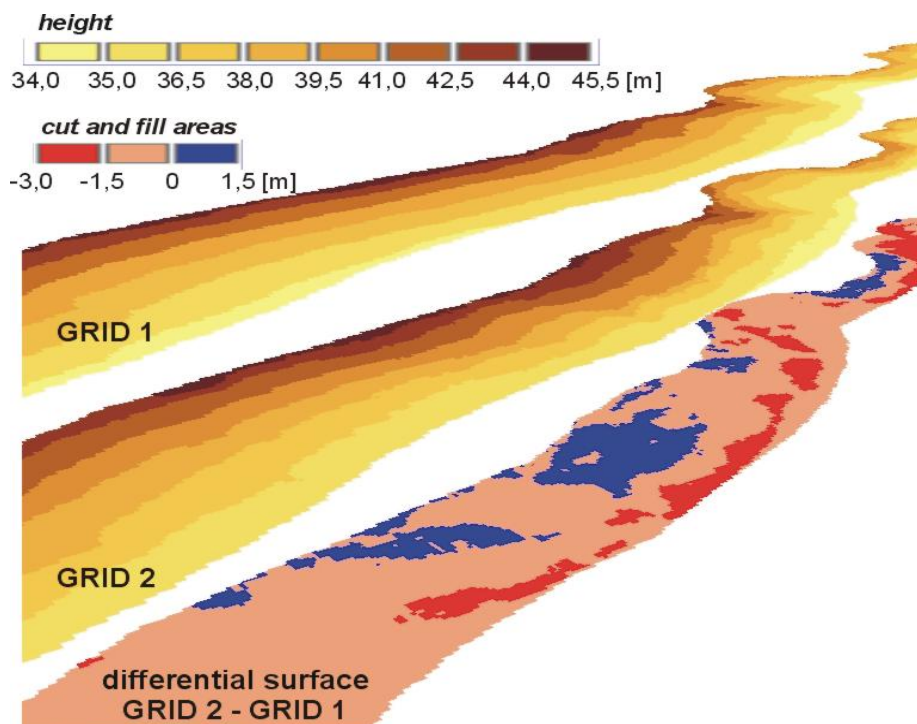


Fig. 8. GRID surfaces and their differential surface.

## 6. FINAL REMARKS AND CONCLUSIONS

Scanning instruments i.e. scanning tacheometers and laser scanners prove to be effective in scanning of landforms such as cliffs. Through the application of the reflectorless surveying technique, it is possible to observe the whole surface of the cliff,

including the unavailable areas, while observing the regulations concerning the preservation of sea shores. Both instruments have some advantages and disadvantages.

The accuracy as to the location of the points, in case of both instruments is similar and depends primarily on the accuracy of the EDM. The range of surveying is also close – depending on the type of the laser used (impulse, phase). The main difference between these instruments lies in the speed of data collection. The ground scanners observe several to several thousand points per second, while the scanning tacheometers survey up to 20 points per second. The advantage of a scanner is also that it registers the fourth “virtual” coordinate, which informs of the amount of laser light reflected from the object. This information may be used for example to identify objects, which have different parameters of light reflection, or to selection of data.

While conducting a survey on the beach, the weight of the instrument is very important, because it is not always possible to reach the object by car. Scanning tacheometers weigh 5 to 6 kg, while the ground laser scanners are 2 or 3 times heavier. Moreover, the scanners need additional equipment such as outside power supply, specific sighting marks or a laptop used to control the activity of the instrument. The weight of the whole equipment exceeds 60 kg which limits the mobility of the set.

The advantage of scanning tacheometers is the fact, that apart from scanning they can be used in other typical geodetic tasks. Their price is also advantageous, a few times lower in comparison with scanners.

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