TOPOGRAPHY APPLICATIONS IN SURFACE MINNING

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Abstract
Topography plays a fundamental role within the framework of engineering activities undertaken in the mining works, the contribution of this branch of terrestrial measurements being materialized through the specific studies conducted since the design phase of the holding and up to greening the mining area. In the first part of the article we propose an incursion into the methods of calculating the volume of exploited material, in order to present and debate on the special features of these methods of calculation used in the current engineering practice. The second part of this exposure is achieved through the case study, with reference to Stoenești-Plaiul Cheii career, in Argeș county, where we have determined the exploited volumes during December 2015 - April 2016 period.
Key words: *engineering measurements, volumetric calculation, prisms method, surface mining.*

1. Introduction

Topography is the science with fundamental role in surface mining, supporting the proper conduct of the extractive process and providing indispensable information for the commonly undertaken industrial activities.

The products obtained from the topographic activities in a mining area are numerous, but we will list:

- Drawing and updating the topographic plans of the general situation;
- Drawing and sketches of working fronts and any amendments thereto;
- Two-dimensional or three-dimensional monitoring of land and buildings related to the mining exploitation;
- Volume calculations.

In the following, we reflect on the determination of exploited volumes, a calculation undertaken in any mining; we will briefly present the current methods and the particulars thereof.

2. Methods for the determination of the volumes in the mining industry

The determination of volumes in a surface mining area is an autonomous procedure from the other engineering works undertaken, it is an end in itself that requires the collection, processing and interpretation of geospatial data. Basically, a volume of uncovered or exploited material is calculated with reference to a period of time, usually a trimester, information taken in situ standing at the base of calculation, currently processed using specialized software tools and interpreted by the specialists, usually engineers.

The volume calculations shall be carried out using the following methods:

2.1 The transversal profiles method

This method is widely spread and known among specialists as the "match method", being used successfully in linear areas. Basically, this area in question is sectioned by perpendicular profiles.

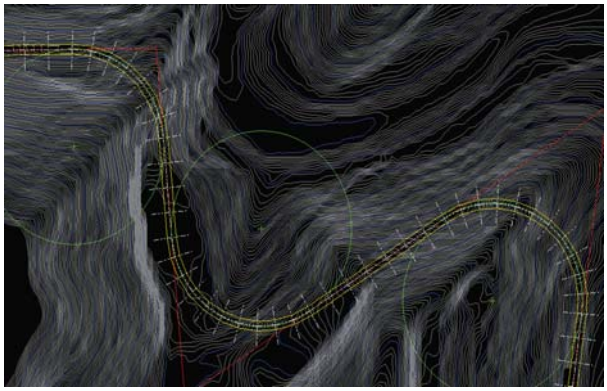

Fig. 1 - *Volume calculations: the transversal profiles method*

The transversal profiles method uses classic processes to calculate the volumes, such as the Trapezoidal method, the calculation based on Simpson's formula, the averages formula, but also improved processes, some based on the Simpson's formula, other based on cubical spline or on Hermite cubical spline.

For two transversal profiles perpendicular to the X axis, carried out in the ends of the range i and i+1, the volume corresponding to the area of the range will be given by:

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$$V = \int_{i}^{i+1} A_{(X)}\,dX \quad 1)$$

Similarly, for two transversal profiles perpendicular to the Y axis, carried out in the ends of the range i and i+1, the volume corresponding to the area will be given by:

$$V = \int_{i}^{i+1} A_{(Y)}\,dY \quad 2)$$

The total volume of excavation or filling using the transversal profiles method is determined by summing all volumes afferent to the elementary surfaces between two transversal profiles, the formula known as Simpson's equation:

$$V = \sum_{i=1}^{n} V_i = \sum_{i=1}^{n} [S_i * \left(\frac{L_i + L_{i+1}}{2}\right)] = \sum_{i=1}^{n} [L_i * \left(\frac{A_i + A_{i+1}}{2}\right)] \quad 3)$$

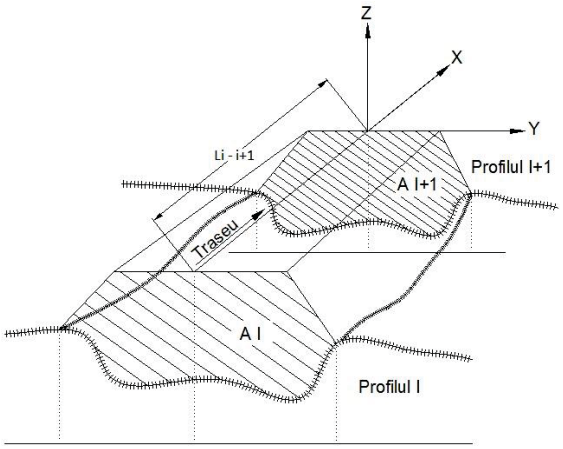

Fig. 2 - *Characteristic elements in volume calculation using the transversal profiles method*

The accuracy of the volume determination using this method is given by the following factors:

- The number of the transversal profiles - the higher this number, the calculated volume is closer to reality;
- The shape of the studied terrain;
- The orientation of the transversal profiles - must be perpendicular to the area of study, as shown in figure 1.

2.2 The prisms method

The prisms method is mainly used in calculating volumes, underpinning the majority of computing software. This method involves dividing the area into elementary triangles or rectangles, these being the bases for the infinity of prisms to represent faithfully the studied terrain.

The volume V_i of a straight prism with triangular base is calculated from the projection surface, the gray area in the figure on the right below and the centers of gravity of triangles of the two surfaces defining the volume, located at a distance di relative to one another.

$$V_i = A_i * d_i \quad 4)$$

where: $$A_i = \frac{l^2 + \sqrt{3}}{4} \quad 5)$$

The total volume of the two surfaces is given by the sum of all the afferent volumes to the straight prisms in the studied area.

$$V = \sum_{i=1}^{n} V_i \quad 6)$$

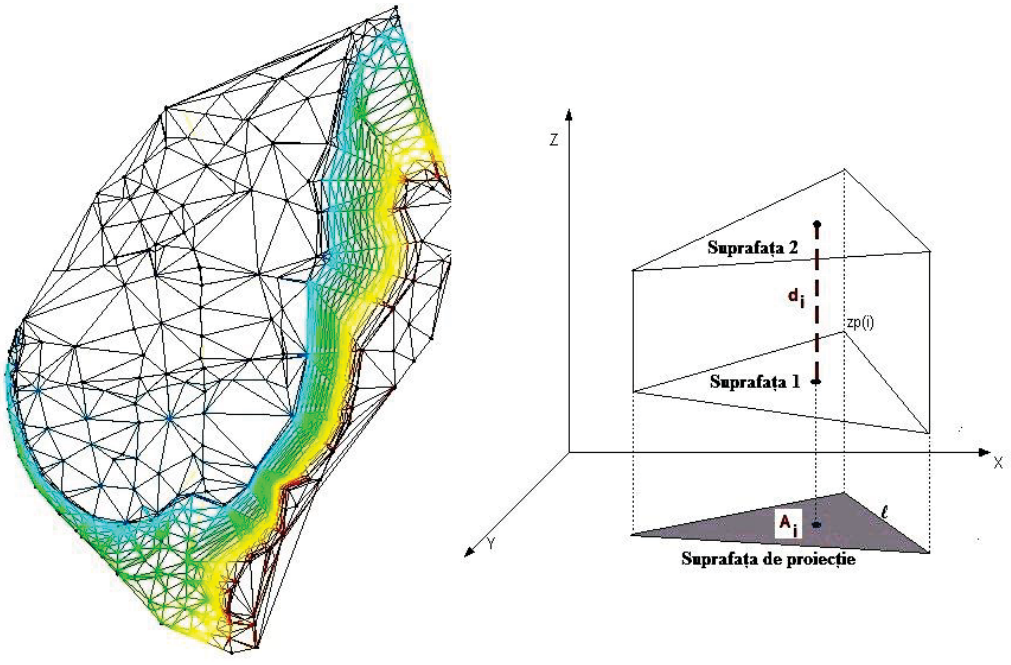

Fig. 3 - *Network of triangles (left) and the principle of the determining the volume of a straight triangular prism (right)*

Surfer® 13 software, based on the prisms method, calculates the volume using the coordinates X, Y and Z of an object using the method of linear interpolation; the volume under the function f(x,y) can be determined by using the double integral:

$$V = \int_{X_{min}}^{X_{max}} \int_{Y_{min}}^{Y_{max}} f(x,y)dx\,dy \qquad 7)$$

Another software, Global Mapper TM v12, also uses the prisms method for determining the volumes, the studied area being divided into an infinite number of minimum considered squares, then by applying the formula:

$$V = \sum_{i=1}^{n} V_i = \sum_{i=1}^{n} H_i * \text{Mărimea pixelului}\ ,i = 1, \dots, n \qquad 8)$$

where i - the infinitesimal square in the studied area

The precision of the prisms method is determined by the accuracy of the digital model to approximate the actual studied area.

2.3 Photogrammetric methods

The photogrammetric method in calculating volumes is relatively new, being used successfully in inaccessible areas, areas of risk, where classic measurements are not suitable.

When using the photogrammetric methods, the field measurements are short duration, classic measurements are needed for determining the control points; where technological developments have been made, the U.A.V. systems have embedded G.N.S.S. receivers.

Short distance photogrammetry uses a multitude of overlapping images, taken from different angles for obtaining the 3D model of an object and then to use it in order to determine the volume of the object.

Fig. 4 - *Short distance photogrammetry in calculating volumes, in accordance with [5]*

2.4 Laser scanning in determining volumes

3D laser scanning is a relatively new technology used in terrestrial measurements, at small scale in mining areas. This modern technology implies the acquisition of geospatial data in the rectangular-coordinate system X, Y and Z with a laser beam, resulting a "point cloud"; through data processing with specific programs, we can obtain including the volume of a surface.

2.5 The reduction of regular geometric shapes

This method implies reducing complex, irregular surface areas, to regular geometric shapes, whose parametric equation are known. It is a rarely used method in current engineering practice, due to the fact that the favorable reduction situations are not very common. The reduction shall be made especially to geometric shapes such as the cone, the trunk of the cone, in order to determine the volumes of such areas.

2.6 Determining volumes by using contour lines of the terrain

This method is rarely used, especially in calculating expeditious volumes, which do not require high accuracy. The obtained accuracy depends on the precision of the determination of contour lines accuracy.

3. Case Study: Stoenești-Plaiul Cheii career, Argeș county

In Plaiul Cheii career, Stoenești village in Argeș county, an important multinational company in the construction materials industry exploits clay, used in conjunction with chalk, which is exploited in Mateias- Hulei Hill career, in order to obtain the premixture, a material which lies at the base of cement production at the factory in Câmpulung Muşcel, Argeș county. Calculations of trimestrial exploited volumes are performed on the basis of carried out measurements.

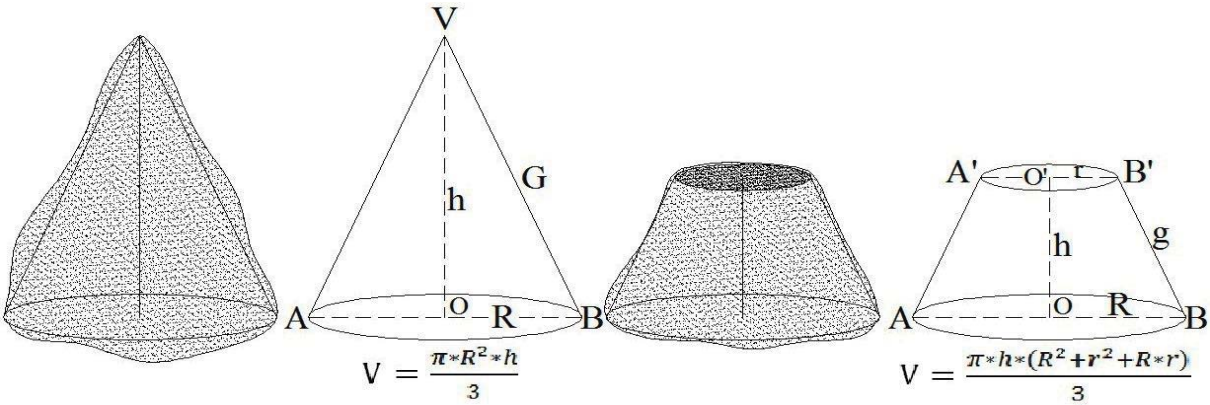

Fig. 5 - *Regular geometric shapes and their characteristic volumes*

Fig. 6 - *Surface mining Stoenești- Plaiul Cheii career*

In the fourth trimester of 2015, December, surveys have been carried out using G.N.S.S. technology, outlining the location and the geometric shape of each existing operating front from within the perimeter of the surface mining area. The measurements have been carried out using three G.N.S.S. receivers, Stonex S9III Plus, 2014 generation, using the kinematic RTK method , radio connection UHF, internal radio Pacific Crest XDL 2W with the horizontal accuracy up to ±0.8cm+1 ppm and vertical accuracy up to ±1.5 cm+1 ppm. A base receiver was used, located on a landmark with known coordinates and two rover receivers simultaneously, one on the lower part of the tread and one at the top.

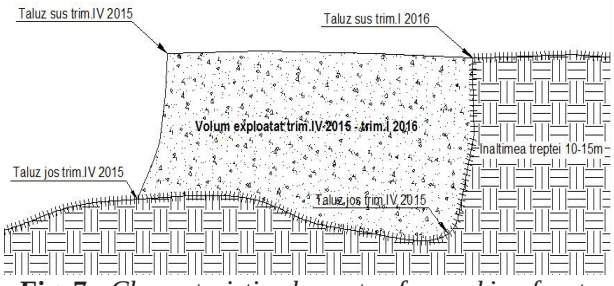

Fig. 7 - *Characteristic elements of a working front*

In April 2016, surveys were conducted in Plaiul Cheii career, in order to determine the volume of exploited material to date, compared to the previous measurement using the same method and equipment as in the previous step.

The points of interest for a working front are top slope, bottom slope, elevation for the upper part of the tread and also for the lower part, used to calculate the height of the tread as the elevation difference , designed between 10 and 15 m. The surveys carried out in December 2015 have been processed and we were able to obtain the digital terrain model (DTM) in this trimester. The same operation was carried out in April 2016 for each active working front. After performing this operation, the two digital terrain models were overlapped and by subtracting from the current digital terrain model the previous one, we have determined the volume of exploited material between the two trimesters of work.

During the mentioned period, materials from two working fronts have been extracted, the total volume being exploited was determined using the prisms method, with specialized software, Sierra Software Geomatics Suite 2009, TopoLT v11.4 and AutoDesk Auto CAD Map 3D 2016

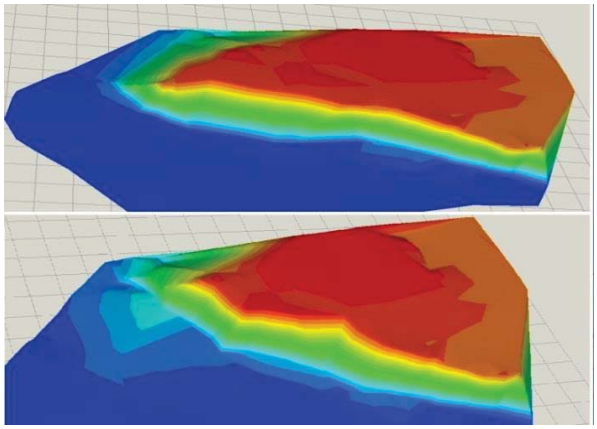

Fig. 8 - *The digital terrain model using TopoLT v.11.4*

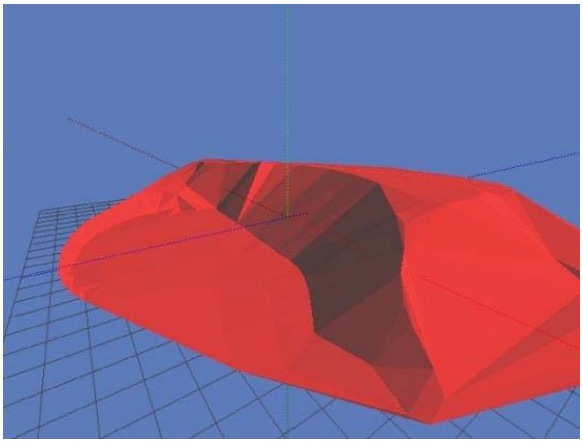

Fig. 9 - *The digital terrain model using Siera Topko 2009*

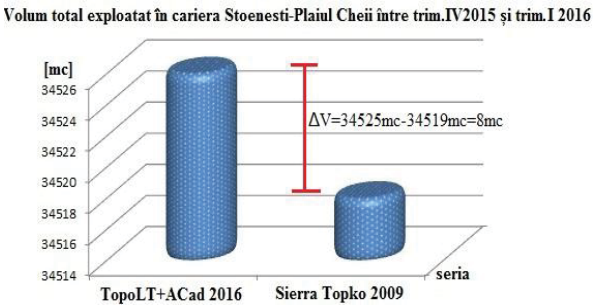

Fig. 10 - *The total exploited volume in Stoenești-Plaiul Cheii career between the 4th trimester of 2015 and 1st trimester of 2016*

In the above chart we can see a difference in 8mc of material between the two results due to the calculation of each software. Compared to the total volume of the excavated material this result is insignificant.

4. Conclusions

Regarding the software that were used, TopoLT v.11.4, used in conjunction with Autodesk AutoCAD Map 3D 2016 and Sierra Topko Geomatics Suite 2009, both use the prisms method for calculating volumes. It is expeditious to use the two versions of the calculation, with a plus to TopoLT v.11.4 - Autodesk AutoCAD Map 3D 2016 on data processing time.

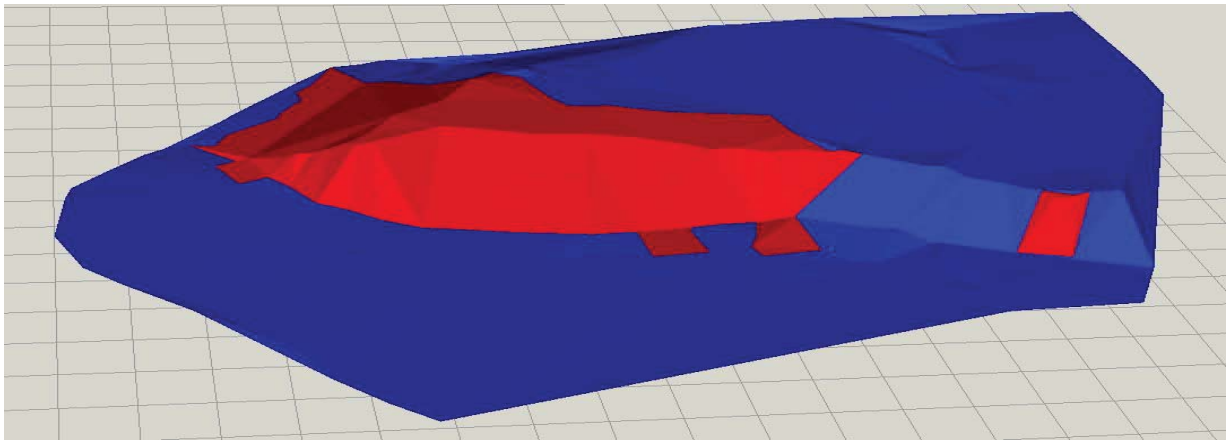

Figure 11 - *The digital terrain model (DTM) of the exploited volume in a working front area. Red - cut; Blue – Stagnation*

Sierra Topko Geomatics Suite 2009 has an advantage for detailed reports extraction, the calculation of volumes being shown for each triangular straight prism created, centralizing the area, the volume of cut and the volume of filling in a table in *.pdf or *.rtf format, while the first variant TopoLT v.11.4 - Autodesk AutoCAD Map 3D 2016 only shows the summary of calculation. This is important because the volume calculation method shall be presented in detail in many situations, for example reporting exploited volumes operated by the National Agency for Mineral Resources.

Both TopoLT v.11.4 software, used in conjunction with Autodesk AutoCAD Map 3D 2016 and Sierra Topko Geomatics Suite 2009 software are viable solutions in achieving volumetric calculations,

successfully used for the requirements of the mining industry.

Regarding the methods underlying the determining of exploited volumes, we may forfeit the following aspects:

- The prisms method is the fastest method in calculating volumes and can be easily programmable in software, can perform calculations of volume for irregular, complex surfaces with a high precision.
- The most accurate method for calculating volumes is laser scanning method, due to the acquisition of a large number of points in the field.
- The transversal profiles method is mostly used when the working front is linear, in the case of curved details, the transversal profiles must be perpendicular to the front, so not parallel between them; To reduce errors induced by this, the number of profiles must be high, in such a way to reveal the geometric reality in the field.
- The photogrammetric method increases as weight in determining volumes with improving the calculation systems, the software products, the advantage of the procedure being the acquisition of data in the shortest time, data processing being performed by specialized programs that require graphic workstations.
- Reducing the volumes to regular shapes and therefore their determination is rarely used in current engineer practice, but it is used to determine the patricular volumes, stored in such a way as to fit this calculation method.
- Using contour lines in determining volumes is a low accuracy method, the calculation being expeditiously, this method depends on the accuracy the contour lines of the studied surface were determined with.
- The time allotted for the calculation, the accuracy in determining the volumes, the equipment, the available software are features that dictate the use of a particular method of calculation.

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