Evaluation of the quality of the road infrastructure with the photogrammetry technique

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Abstract. Solutions that are integrating different modern techniques related to a new or an existing road, using non-destructive test brings several advantages which the content of the article highlights. Comparing the current method used in the road technique AND 540 and the aerial scanning techniques, the main element that stands out is the speed of accomplishing an ample work which consists in the 3D processing much faster and more accurately. The article presents a short current stage of these applications in the field of civil engineering. Creating 3D surfaces that it compares with what it was initially and also processing registered the deformations and displacements. A case study of a road sector is also presented to highlight everything that this technique brings.

1. Introduction

Specialists in the field are continually looking for an effective analytical tool to assist in analysing pavement structures, taking into consideration the in-service condition of the road. This paper addresses the problem of using photogrammetric systems as a support for topographic and geodetic works in the field of roads constructions.

The modernization, rehabilitation and construction of roads and works of art have required a significant increase in the last period, the need comes from the fact that the infrastructure is aging the need for investment, in this context the use of new technology brings increased speed. Photogrammetry as accurate non-contact measuring method provides powerful means for solving different tasks in road surface reconstruction and analysis. The range of dimensions concerned in road surface analysis can have great variation from tenths of millimeter to hundreds of meters and more [1]. The data provided in this way significantly shortens the time but also improves the process of collecting information from the field, taking into account the accuracy of the process as seen in figure 1.

Through this paper, the main goal is to present an efficient, working alternative to facilitate the work in terms of identifying and assessing the state of degradation of bituminous pavement for roads, based on the AND 540 Romanian standard, as a guide for identification and classification types of degradation and using elements in the field of photogrammetry for taking over and analysing field characteristics.
2. Advantages and disadvantages
Both, the classical method of identifying and evaluating the state of road degradation, and the proposed method, have advantages but also disadvantages. Compared to the classic method, regulated by AND 540 [2], the proposed method has as its first advantage the efficiency given by the reduced working time but also the quality of determining the results. A very large amount of data can be obtained in a relatively short time compared to the classic method, without going through the entire target area. In addition, the chances of errors of the operator interpretation are much reduced because the entire area is analysed, and by the classical method, can be identified degradations that are overlooked from the negligence of the operator. Moreover, the situation in the field from the moment of taking over the data, remains at the disposal of the operator for possible ambiguities. Then, another very important advantage is the accuracy of the determinations. The evaluation of the degradation appeared at the level of the bituminous coating is done digitally on the 3d model using specialized software, which eliminates the reading errors on the roulette or the approximation errors, determining precisely the dimensions of the degradations. As a main disadvantage is the fact that working on this method is not provided in any norm, determining the user to create his own working method using his knowledge in the field but also the AND 540 norm. Then, another disadvantage is the high cost of the equipment used but also of the software.

3. Methodology for determining the quality of road infrastructure
The problems of the road structure design require complex approaches that needs a higher quantity and quality of input data in four major categories: traffic; material characterization and properties; environmental influences; pavement response and hazard models [3-7]. The problem of maintaining the viability is complex, on the one hand due to the economic side of maintaining and monitoring the state, the mechanisms for prioritizing the works, the policies that changes periodically [4].

The evaluation of the road pavement degradation condition is currently done in Romania, according to the AND 540 norm, visually by going through the analyzed surface, followed by the processing of the data collected from the field and their analysis in order to determine the technical condition of the road. After obtaining these data, the technical expertise is drawn up, based on which the amount of works necessary to carry out the improvements of the technical condition of the road is determined.

The proposed method involves the identification of the area that has to be analyzed, planning the flight as seen in figure 2a, materializing and determining the control points, performing the flight, downloading and processing the images and analyzing the data obtained after processing.

Flight planning is done using Mission Planner software. The following elements from the land will be taken into account: the inclination of the land, elements that are found in the vicinity - vegetation,
constructions, lighting poles, etc. "The flights followed a conventional photogrammetric pattern with vertical photographs and image overlaps of the order of 70 - 80% to guarantee a proper vertical accuracy and enough redundancy" [8]. The take-off of the aircraft is always done from the outside of the targeted perimeter, from a flat ground, free of bushes, trees, constructions or other elements that can make it difficult to take off and later land. It is recommended that the flight has to be made around noon when the sun's rays form at right angles to the ground surface and the elements in the ground, avoiding shadows. The height from which the flight is made is done depending on the accuracy and density of the desired point cloud. The higher the flight altitude is, the lower the accuracy of the details are. In this case, the flight was made from 7 m above the ground and the obtained accuracy was 1.5mm / pixel. The area on which the flight is made, is composed of the road sector to be analyzed and areas in its immediate vicinity, so the road sector will be more easily framed in the area. The flight direction is chosen so that the route is as short as possible.

**Figure 2.** (a) flight planning; (b) data interpretation using Agisoft Metashape software.

In order to the existing points in the digital terrain model and the points in the field to coincide, a number of control points/benchmarks is needed to connect them. The establishment of their location is done by analysing the targeted area. The control points will be uniformly located on the entire targeted surface at optimal distances. "The benchmark system should be sufficient to cover overlaps of set-ups but not more than 200 m apart. The benchmark system must be check levelled to a 2 mm/km closure [9]. In this case, the checkpoints were marked with black carioca or metal nails and highlighted with orange spray. The determination of the coordinates of these points is done with the help of the GNSS RTK system by making successive measurements for 60 seconds in point and calculating the average position.

The images are downloaded using a memory stick or SD card. Each image will contain the following instructions: the name of the image, the time when it was taken and the approximate position. This information is needed when processing the images and aligning them. The image processing is done using the Agisoft Metashape program as seen in figure 2b.

Agisoft Metashape is a program that allows you to obtain point clouds, the DEM model of the terrain or orthophotograms based on aerial photographs. Uploading photos and the first step is to align the photos. This is done using the Align photos command in the Workflow menu. At this stage, the photos are aligned with each other, depending on the approximate position and the common elements in each photo. A sparse point cloud is also formed (tie points), consisting of the identified common elements in each photo. In this case, the sparse point cloud is about 265,683 points. Markers / control points are used for a better reconstruction of the model. More precisely, the operator identifies the field markers in the photos and makes the connection between them by loading in the program their measured coordinates.
Figure 3. Control points / check points on the field.

Figure 4. Photo alignment, sparse point cloud and markers.

After entering the checkpoints, the photos are realigned. After performing this process, the generated point cloud, as well as the following procedures are in the WGS84 projection system given by the coordinates of the control points.

The next process is Build dense cloud. Three-dimensional point clouds are the main result of both terrestrial and airborne laser scans [10]. The points in the dense cloud are calculated by rectifying the pairs of successive images thus according to the orientation parameters and then an algorithm is used that matches each pixel in the image pairs. In this case, the resulting point cloud is composed of 654,296,860 points. The points in the dense cloud are so detailed that they faithfully reproduce the shape of the element in the field.

From the dense cloud can be generated "Mesh" - obtained from the creation of networks of polygons formed by the points in the dense cloud. It reproduces, better than dense cloud, the shape of the details in the field, representing a three-dimensional model of the terrain as seen in figure 5.

To better highlight the texture, "Tilled model" and "Textured model" are made. The difference between all these models lies in the details.

The last stage of image processing consists in making the orthomosaic, on which, later, the defects will be identified. The resulting orthomosaic has the size of 13928 x 72346 and an accuracy of 1.5mm / pixel.
4. Results interpretation

On the orthomosaic and the other models resulting from the image processing, the next step is the interpretation of the results which consists in the identification and registration of the defects appeared at the level of the road infrastructure. Defects are recorded according to: shape, surface, length, depth, exact position, etc., according to the indications in AND540. Each defect is registered in a specific layer, depending on the type. The characteristics of each type of degradation are recorded in an attribute table corresponding to each layer.

Following the analysis, the following defects were identified: spider web tiles, slab tiles, slits and longitudinal cracks, seals and sealed surfaces, potholes, grooves, cracks and transverse cracks, cracks and longitudinal cracks due to the reflections of concrete slab joints, cracks at the edges, peeling, polished surfaces, pinched surfaces.

From the category of structural type degradations, the most common types of degradations were: tile tiles, longitudinal cracks, seals and sealed surfaces and pinches.

The pinches, according to AND540 "are the defects of bituminous layer, with a diameter of less than 750 mm, located in heavily eroded, tiled, cracked or compacted areas". These are evaluated according to the maximum depth and diameter.

The orthomosaic and the other models obtained based on which the field data is interpreted are loaded in the Qgis software. Based on them, cross sections are extracted in the desired areas to determine the depths as seen in figure 6.

If, by the method provided in AND540 “The surface of the potholes is determined by framing it in a rectangle, appreciating the size of the sides a and b, in meters”, the determination of the surface of the potholes in the presented method is much more precise: the exact shape of the pothole is given by an irregular polygon, identical to its real shape whose surface is calculated automatically, thus obtaining a result much closer to reality than by the classical method, especially when it comes to pinches with irregular shapes as seen in figure 7.
At the level of the analyzed area, a number of 84 potholes with surfaces varied between 0.002 and 0.32 m² was identified. Each pinches type defect was registered in a specific layer, and for each one the coordinates, the surface is known and the depth can be determined, and depending on these details the severity level is established. After identifying all the pinches, a map of the potholes with their position and shape is obtained as seen in figure 8.

Similarly, the seals and sealed surfaces are identified. These were found in very large numbers, 62, on the analyzed area, with areas ranging between 0.0375 and 81,713 m² totaling a total area of 288,12573 m². In the same way, the alligator cracking’s, the longitudinal cracks, the edge cracking, the depression, the rutting’s, with pinches and beeches are also identified.

Identification and registration of the types of degradations, for which the evaluation is made by measuring the length: longitudinal cracks and fissures, transverse cracks and fissures longitudinal cracks and fissures due to the reflection of cement concrete slab joints, and cracks it is made, by the method presented, on the orthomosaic. The defects are identified on it, and the shape
is registered in a line type layer. The determination of the severity level is done by measuring, on the orthomosaic, the opening of the degradation in question. The value of the crack length is calculated automatically for each identified element and is registered in the attribute table together with the other details. Finally, the crack map is obtained, and in the present situation, the longitudinal and transverse cracks were evaluated in a single layer as seen in figure 9.
Another important piece, but also useful for the analysis of a road sector in terms of defects but which is also useful later on in the design of rehabilitation works, is the level cube plan. Following the image processing process to obtain DEM - Digital elevation model. From this model, level curves can be generated at intervals of millimeters, centimeters or tens of centimeters as seen in figure 11. Level curves help a lot in identifying and determining depths for potholes or cracks, cracks, veils and unevenness.

5. Conclusions
The technique of measurements in the field of engineering topography, has evolved so much that in the case of elevations made to modernize roads, their use bringing important benefits both technically and economically. The time to perform the measurements is considerably reduced, this benefit is highlighted by the final costs of the work performed. The number of points acquired in a short time is very large, this helps to interpret very correctly the scanned objects even small ones. The software for processing the measurements resulting from the scan consists of several methods of compensation and registration, this fact allows the user to choose the appropriate method of processing depending on the characteristics of the study being performed. The reports with the results can be analyzed, compared and evaluated for the realization of statistics. The creation of sections, longitudinal and transversal profiles is done automatically, by imposing the sectioning interval. Sections and profiles, as a final product, can be obtained in the point cloud system (national system) or in a local coordinate system of each section for real-time relative comparisons.

The errors and mistakes due to the human staff are reduced in a very high percentage, the results being more objective and the situation in the field from the moment of making the measurements can be reviewed as many times as necessary without going on the site.
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