Applications of Low-ceiling Photogrammetry Using UAV to Verify the Thickness of a Mineral-asphalt Package

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Abstract

Low-ceiling photogrammetry using unmanned aerial vehicles (UAVs) is becoming more and more widely used in engineering works. The use of this method is supported by the possibility of remote measurement quickly and at the same time with appropriate accuracy. UAV measurements are extremely useful over large areas, including construction sites. Such monitoring enables constant control of the progress of construction works, with the possibility of taking measurements. In the research, the authors verified the possibility of using a tool such as a UAV in the inventory of road investments, i.e. to control the thickness of the mineral-asphalt package. A testing ground was used for this purpose. Based on the raids performed before and after applying the mixture, the resulting dense point clouds were compared. Thanks to this, the actual thickness of the fresh surface was checked with the design assumptions. Results ranging from 9 to 11 cm were obtained, which indicates satisfactory compliance with the design.

Keywords: *photogrammetric measurements, unmanned aerial vehicle, pavement inventory, mineral-asphalt mixture*

1. Introduction

Technological development has contributed to significant progress in the implementation of measurement tasks. The use of remote techniques such as photogrammetry (airborne, satellite), airborne laser scanning or radar interferometry is a common activity in field research. (1–3). The possibility of performing measurements at a distance and their effectiveness (a large number of points measured in a short time) make these methods more and more popular. Particular attention should be paid to low-ceiling photogrammetric measurements using unmanned aerial vehicles due to their low cost in relation to the obtained measurement accuracies. The photos created as a result of the raid are processed in software to obtain a dense point cloud, 3D models, hypsometric maps and much more. The data obtained in this way in the form of XYZ coordinates can be used to determine the distance, area and volume of the examined object. By performing measurements at given time intervals, it is possible to compare the obtained point clouds and thus observe the displacements or deformations of the object (4–6). Photogrammetric methods, including those using unmanned aerial vehicles, have been used in many engineering works, including: for measuring very tall, hard-to-reach objects, such as chimneys, masts, poles (7). UAV measurements are extremely useful over large areas, including construction sites. Such monitoring enables constant control of the progress of construction works, with the possibility of taking measurements (8–10). Additionally, it is a helpful tool for observing terrain deformations, including steep slopes, where direct geodetic measurement could endanger the measuring person (11–13).

The research attempted to verify the usefulness of low-ceiling photogrammetry for assessing the uniformity of the thickness of the mineral-asphalt package on the example of an experimental research site.

2. Research Characteristics

2.1 Research site

The research site was a separate track with circular traffic (Figure 1). The total length of the track was 85 m. In cross-section, the width of the lane was 3.5 m.

Ultimately, the research program included a comparison of mineral and asphalt mixtures of various compositions with the so-called references fully compliant with applicable requirements (14). The research site consisted of several observation sections where the total thickness of the mineral and asphalt package was designed, 10 cm and 11 cm thick. The mineral and asphalt package consisted of a wearing course (4 cm) and a binding layer (6 cm) or base layer (7 cm). In order to be able to carry out tests in accordance with the assumed program, it was necessary to verify the actual thickness of the mixture placed with the designed assumptions. Therefore, observations from the flight using low-ceiling photogrammetry were used.

Fig. 1. View of the research site.

2.2 Photogrammetric measurements

Field tests to verify the thickness of the mineral-asphalt package were performed using low-ceiling photogrammetry. An unmanned aerial vehicle (commonly a drone) was used for this purpose. The research was reduced to two measurement missions: before and after the installation of the mineral-asphalt mixture package. The measurements involved taking a series of photos, which were then processed using a specialized program. Point clouds were generated in which each measurement point in the field received x, y and z coordinates. The flights were carried out using a quadrocopter weighing over 1.3 kg. The drone was equipped with a camera with a 1-inch 20 MPix matrix (Figure 2a)

Missions with the following flight settings were planned over the research area:

- Flight trajectory (double grid) usually dedicated to 3D models;
- Flight height 30 m, which translates into a terrain pixel of 8 mm;
- Speed 4 m/s;
- Camera angle 80 degrees;
- Transverse and longitudinal photo coverage 80%.

Each mission lasted approximately 10 minutes, during which 180 photos were taken.

Photogrammetric processing began with aligning the photos and identifying ground control points - previously measured using GNSS (Figure 2b). This stage allowed for the generation of dense point clouds. The obtained 3D models of the zone of the tested pavement section are shown in Figure 3.

Fig. 2. a) Preparing the drone for measurement - before applying the mineral-asphalt mixture, b) measurement of control points using GNSS satellite technology.

3. Observation Results

In order to verify the actual thickness of the built-in mineral-asphalt package, the point clouds obtained from photogrammetric measurements, i.e. those made before and after applying the mixture, were compared. Observing the distribution of the color scale in the research plot, the predominance of the green color indicating values from 0.09 to 0.11 m should be indicated (Figure 3).

Taking into account the designed surface thickness values, it should be noted that the results obtained from photogrammetric measurement are in good agreement with the design assumptions, because a package of mineral and asphalt layers with a thickness of 11 cm (sections on the left) and 10 cm (sections on the right) was built.

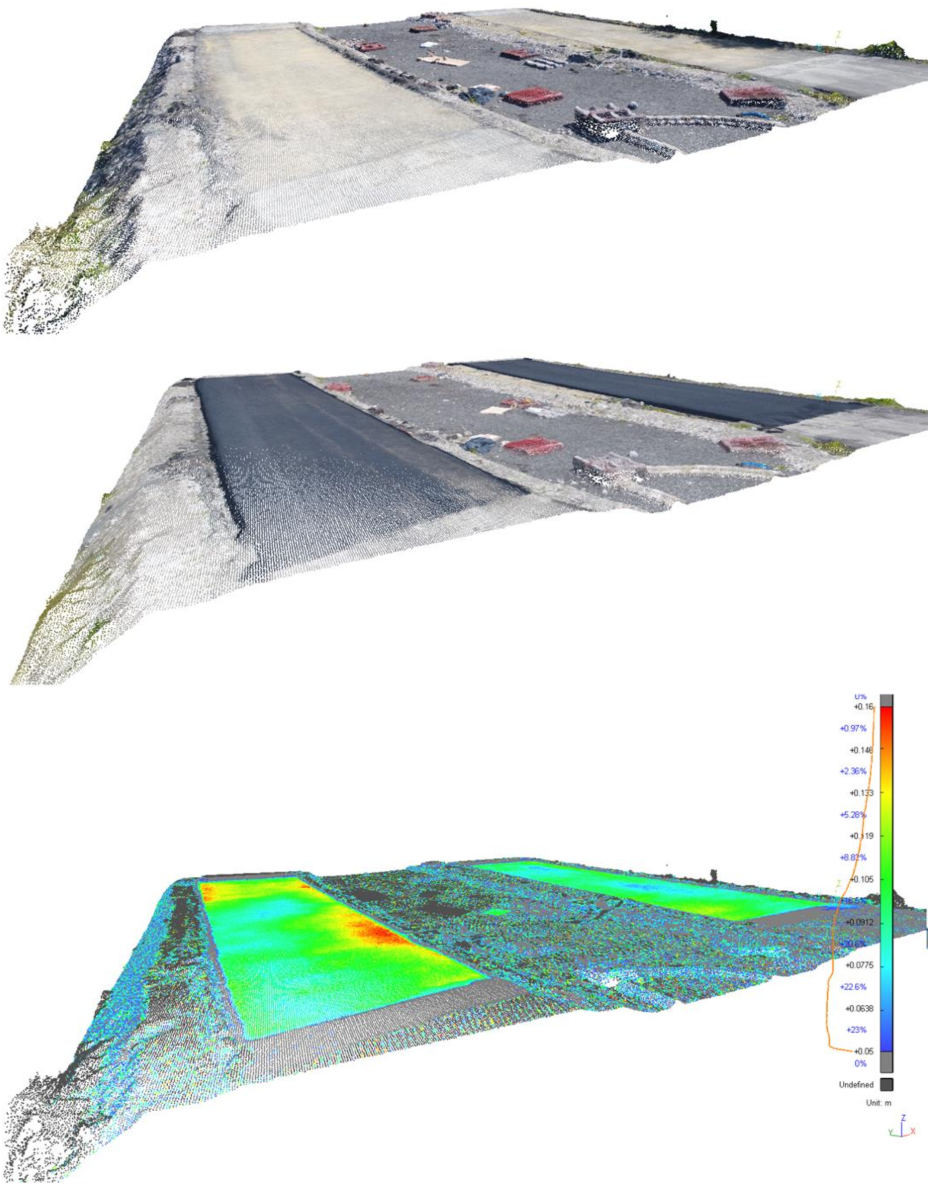

Fig. 3. Obtained point clouds before and after applying the mixture and their comparison.

4. Conclusion

The paper presents an example of road surface observation using low-ceiling photogrammetry. As observed in the tests, low-ceiling photogrammetry can be successfully used to control the uniformity of the thickness of the mineral-asphalt package. Detailed results describing the thickness of the package may concern selected longitudinal or transverse profiles, which can be successfully used for further computational analyses, e.g. when determining stiffness moduli and fatigue life.

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