Revista ALCONPAT

Revista de la Asociación Latinoamericana de Control de Calidad, Patología y Recuperación de la Construcción

Use of unmanned aerial vehicle (UAV) in the identification of surface pathology in asphalt pavement

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DOI: http://dx.doi.org/10.21041/ra.v7i1.161

ABSTRACT

The present research had the purpose of developing an alternative and new procedure to identify the superficial pathologic manifestations on asphalt pavement from a stretch of highway TO-050, in Palmas - TO. As tools were used: an unmanned aerial vehicle (UAV), flight plan and image processing software, mosaic of orthophotos and Digital Surface Model (DSM) of the studied area. Through the visual interpretation of the generated products it was possible to identify the pathological manifestations in its variety, comparing obtained data from the images with data of in loco inspection. Even presenting a high potential for recognition of compromised areas, it is important to highlight that the instability of the aircraft interferes considerably on the quality of the images generated.

Keywords: unmanned aerial vehicle; pathology; asphaltic pavement.

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Utilização de veículo aéreo não tripulado (VANT) na identificação de patologia superficial em pavimento asfáltico

RESUMO

A presente investigación teve o propósito de desenvolver um procedimento alternativo e inovador para identificar as manifestações patológicas superficiales em pavimento asfáltico de um trecho da vía TO-050, em Palmas - TO. Como herramienta fué utilizado um Vehículo Aéreo No Tripulado (VANT), softwares para plano de vuelo e procesamiento de imágenes, mosaicos de ortofotos e Modelo Digital de Superfície (MDS) da área em estudo. Por medio da interpretaçao visual dos produtos gerados fué posible identificar as manifestações patológicas em sua variedade, confrontando datos obtidos por medio das imágenes com datos de inspecciones no local. Mesmo apresentando elevado potencial de reconocimiento de áreas comprometidas, cabe destacar que a instabilidade da aeronave interfere consideradamente na calidad das imágenes geradas.
Palavras-chave: vehículo aéreo no tripulado; patología; pavimento.

Uso de vehículo aéreo no tripulado (VANT) en la identificación de falla superficial en pavimento asfáltico

RESUMEN

La presente investigación tuvo el propósito de desarrollar un procedimiento alternativo e innovador para identificar las manifestaciones patológicas superficiales en pavimento asfáltico de un tramo de vía identificado como TO-050, en Palmas - Tocantins. Como herramienta se utilizó un Vehículo Aéreo No Tripulado (VANT), softwares para plano de vuelo y procesamiento de imágenes, mosaicos de ortofotos y Modelo Digital de Superficie (MDS) del área en estudio. Por medio de la interpretación visual de los productos generados fue posible identificar las manifestaciones patológicas en su variedad confrontando datos obtenidos por medio de las imágenes con datos de inspecciones en sitio. Aun cuando presenta un elevado potencial de reconocimiento de áreas comprometidas, hay que destacar que la instabilidad del vehículo interfiere considerablemente en la calidad de las imágenes generadas.
Palabras clave: vehículo aéreo no tripulado; patología; pavimento asfáltico.

1. INTRODUCTION

In virtue of few investments in railway and waterway, and also the high cost of air transport, in Brazil, the major part of load transport and people are made via roadway. Among the existent types of road pavement there are: the flexible (which coating is constituted by bituminous material) and the rigid (formed by concrete slabs). (LUCENA, 2016)

The road pavements, according to DNIT (2011), configure a valued heritage, which must be conserved and restored in order to guarantee its preservation. Any interruption or reduction on the intensity or on the frequency of maintenance service of those pavements, implies on the increase of costs of operational vehicles and on the necessity of each time bigger investments with recovery. According to Vieira et. Al., (2016), the precocious degradation of rehabilitated and also new pavements, is related to the application of inadequate projects for the highways, projects that many times are elaborated without any detailed survey of the pavement or of the situation in which the ground is found. In some cases, occurs that the evaluation methods of the real condition of the road are used in an inappropriate or inefficient way.

The identification of the pathology has the goal of evaluating the conservation state of the asphalt pavement, permitting a diagnosis of the functional situation and, with that, establish solutions

technically adequate, indicating the best alternatives for the maintenance or restoration of the pavement. (MARCON, 1996)

Nowadays, there are evaluation methods of asphalt pavement that can give information in which are possible to know the real condition of the asphalt pavement Surface. With those results, it would be possible to do the best way for prevention action or even a restoration on the highway. (SHAHIN, 1996)

In this context, the general objective of this article is to evaluate the potentiality of the images obtained by UAV as subsidy in the process of pathology identification in pavements, with application in a stretch of the highway TO-050, in Palmas – TO.

2. UAVS AND THE IDENTIFICATION OF PAVEMENT PATHOLOGY

Even though the visual inspections are indispensable and the quality of the generated product brings in a reliable form the state of conservation of the highway stretches, this process has been gaining support with the advance of new technologies. One of those is remote detection via UAV, that presents as characteristic the fast data acquisition and the mobility towards temporal diversity.

According to Bento (2008), the integration of imaging sensors with position sensors (Global Navigation Satellite System – GNSS) in UAV platform enables the direct georeferencing, allowing the process of generating Digital Surface Model (DSM) and orthophoto, tools used in this research to seek the identification of superficial pathology in a stretch of highway.

In recent years, the use of UAVs for civil purposes has begun to increase thanks to technological advances, cost reductions and size of sensors related to the Global Positioning System (GPS), pre-programmed flights, IMUs (inertial movement units) and auto -pilots. In this sense, the technology can fill some knowledge gaps by improving the spatial and temporal resolution of the most common current remote sensing systems. (NISHAR et al., 2016)

Breen et al. (2015) reports that cost-effectiveness, ease of use, flight planning and deployment flexibility, the availability of a range of high-resolution sensors and post-processing software give this tool the potential satellite imagery and images of manned aircraft.

3. PROCEDURE

As an intention of evaluate the applicability of images obtained by UAV for mapping and identification of pathology existence in a stretch of the highway TO-050, it is proposed this present study, of methodological exploratory-descriptive and qualitative character.

3.1.Area of study
As sample unit for this research, it was chosen a stretch of the state highway TO-050 of 3,0km approximately. It is a highway of simple lane, paved that connects the cities: Palmas, Porto Nacional and Silvanópolis; it has 124km length. On the roadmap bellow is possible to observe the coverage of TO-050.

The usage of unmanned aerial vehicle (UAV) on mapping and identification of superficial pathology on asphaltic pavement

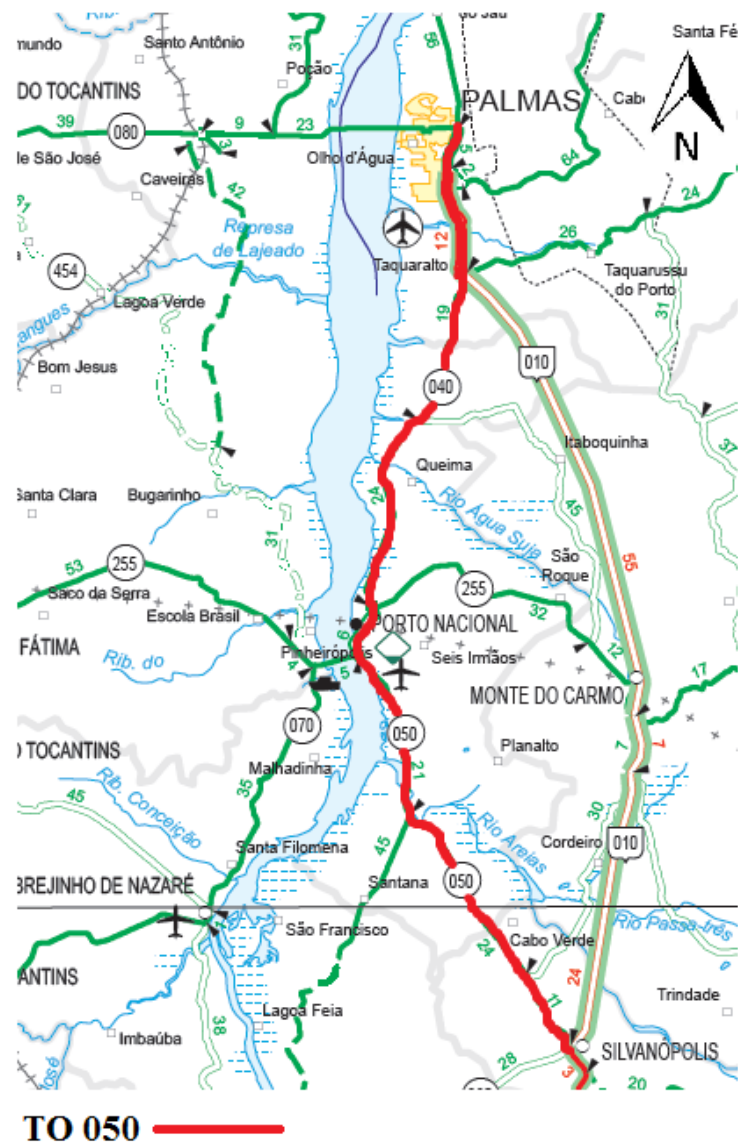D. Cardoso Parente, N. Carvalho Felix, A. Pessoa Picanço

TO 050 ▬▬▬

Image 1. State Highway TO-050 connecting the cities: Silvanópolis, Porto Nacional and Palmas.

Nowadays the stretch in study is considered of extreme importance for the urban mobility of Palmas city, since it connects the central area of the city to the neighborhoods: Aurenys, Taquaralto, Sonia Regina, Santa Barbara and others; thus, presenting a very intense traffic flow of vehicles during the working hours.

3.2. Materials

3.2.1 UAV eBee and softwares of image processing

For collecting images an aircraft model eBee (Image 2) was used. It is comprehended as flying platform attached with specific sensors that allow the obtainment of photographies and videos. The aircraft has incorporated sensors that enables the stability of itself during a mission, as well as the transmission of data that guarantees the direct monitoring off light execution.

The usage of unmanned aerial vehicle (UAV) on mapping and identification
of superficial pathology on asphaltic pavement   163
                        D. Cardoso Parente, N. Carvalho Felix, A. Pessoa Picanço

Image 2. UAV model eBee.

The flight planning is elaborated through the base station with the following set: eMotion 2 software, responsible for programming the flight and the execution of the aircraft route; and a transmission antenna, that allows the monitoring of the flight in real-time, and also, to send the landing command, route changes and obtainment of images. The interface of the software shows important information about battery level, in-loco temperature, altitude, position, duration, flight speed, wind speed, resolution, latitudinal and longitudinal overlap of the area to be covered, and radio link.

For processing the images and generate orthorectified mosaics, the aircraft dispose of a specific software, it is Terra 3D. In this process the points taken by UAV GPS are associated to each corresponding image.

3.2.2 Cameras
The cameras used to capture the images had characteristics suitable to and compatible with the eBee system and the orthomosaic formation application, the two models S110 NIR and S110 RGB, adapted in such a way that they could be controlled through the aircraft's autopilot. The NIR camera will collect data in the near-infrared band and the RGB camera collect image data inside the visible spectrum, which allows it to replicate any color, using as basis a mix of only 3 primary colors and light: blue, green and red.

3.3.Methods

3.3.1 Flight Planning and Image acquisition
Having selected the flight area and the pixel size, the software makes automatically available the area, the estimated flight time, elevation, space arrangement among the path lines and the distance that is going to be flown. The flight plan established for the current research caught sight of superficial pathologies in a three-kilometer patch of highway, using only one set of overlapping flight trajectories and two sensors to capture the images. Image 3 shows the detailed process of the image overlapping.
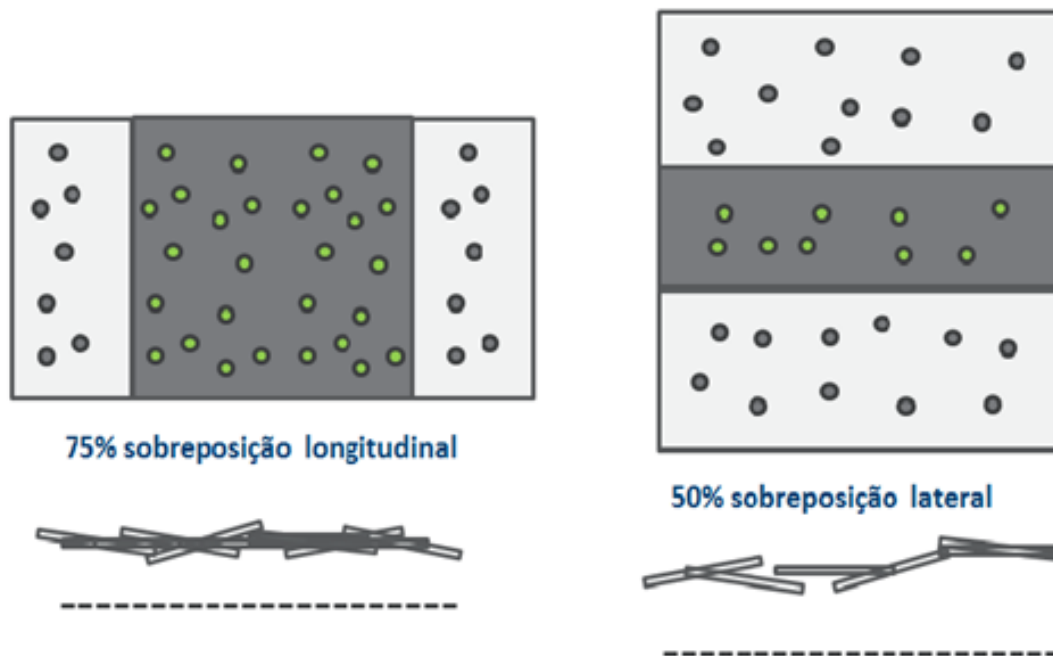
The usage of unmanned aerial vehicle (UAV) on mapping and identification
of superficial pathology on asphaltic pavement
164
D. Cardoso Parente, N. Carvalho Felix, A. Pessoa Picanço

Image 3. Longitudinal and lateral image overlapping

3.3.2 Assembling the orthomosaic

The properly georeferenced mosaic was obtained after a series of steps, which included the removal of errors and distortions brought about by the image acquisition process and had as an objective the of aligning the images to one another as well as to the whole scene.

The georeferencing of the images is made through a software which is compatible with the aircraft and its sensor, since the aircraft has a navigational GPS attached to it. The coordinates acquired were used to guide in the orientation/alignment of all the pictures to form the georeferrenced mosaic. Its acquirement allows the collection of quantifiable data, such as area and volume, making it easier to identify each point in the images.

4. RESULTS AND DISCUSSIONS

4.1. Pavement surface analysis

The pathology analysis of the stretch of highway TO-050 was done using photographic interpretation of the mosaics, which has the objective of identifying and discerning the elements on the Surface, through the spectral response of the two sensors used. Among the range of superficial pathologies found, the ones that stand out are edge breaks, pavement patching and rutting.

Image 04 presents pavement edge breaks in a stretch of the road shoulder. As it can be seen in this image, the loss of material between the road shoulder and the road centerline, caused by an irregular detour and the absence of a curfew, makes it more vulnerable to this kind of weathering.

The usage of unmanned aerial vehicle (UAV) on mapping and identification
of superficial pathology on asphaltic pavement
D. Cardoso Parente, N. Carvalho Felix, A. Pessoa Picanço

165

Image 4. Road shoulder pavement losss

In image 05 the areas affected by patching are being exposed, pathology which has the highest incidence in the stretch overflown. The patches are usually caused by attempts to correct pavement problems, which were in turn caused by depressions, rutting and raveling, alligator cracking and pot holes.
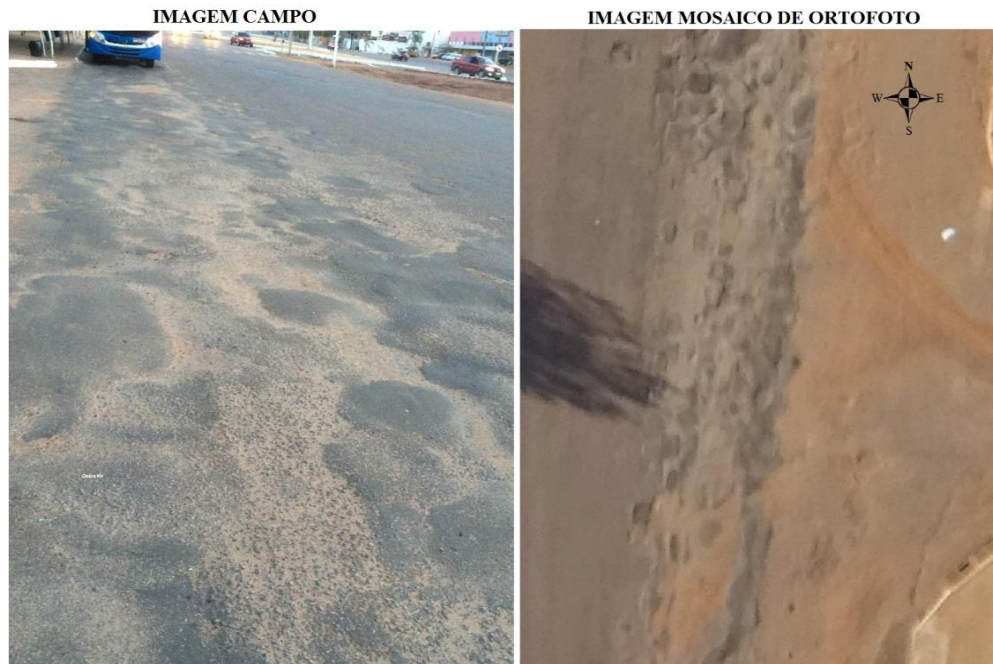

Image 5. Emergency Patching

Rutting is also present in some part of the stretch. The Image 6 illustrates this type of pathology, characterized by formation of depressions on the longitudinal way of the road, followed by rutting or elevation of adjoining areas. This pathological manifestation is related to traffic of heavy vehicles of public transportation (bus), which is more intense in this lane.

The usage of unmanned aerial vehicle (UAV) on mapping and identification
of superficial pathology on asphaltic pavement

D. Cardoso Parente, N. Carvalho Felix, A. Pessoa Picanço

Image 6. Rutting in a stretch of heavy traffic.

The Image 7 evidence an area containing connection of repair on longitudinal direction, located between the old and new pavement executed for the enlargement of the road.
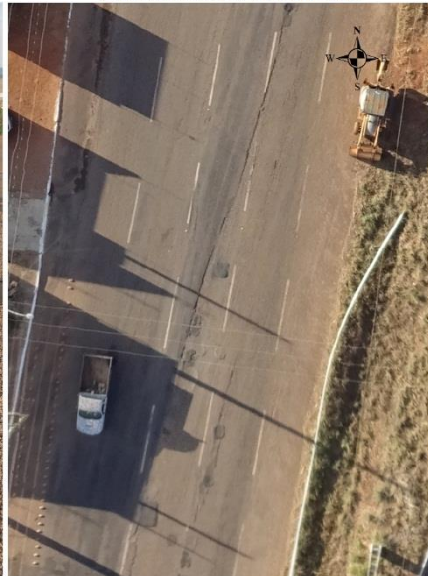

Image 7. Connection of repair.

Compromised areas due to superficial wear can be observed on the Image 8. In these situations, the loss of the asphaltic surface course occurs. That involves the aggregate base, followed by the polishing of the aggregates, exposing them to the vehicles tires, aggravated by the abrasive action of heavy traffic, thus resulting in the loss of the aggregate base course and harshness of the pavement surface.

The usage of unmanned aerial vehicle (UAV) on mapping and identification
of superficial pathology on asphaltic pavement   167
D. Cardoso Parente, N. Carvalho Felix, A. Pessoa Picanço

IMAGEM CAMPO   IMAGEM MOSAICO DE ORTOFOTO

Image 8. Superficial wear

The appearance of bituminous material without the appearance of aggregate base course, also known as exudation, as shown in Image 9, is characterized by having a shiny surface and was also one of the kinds of pathologies identified.
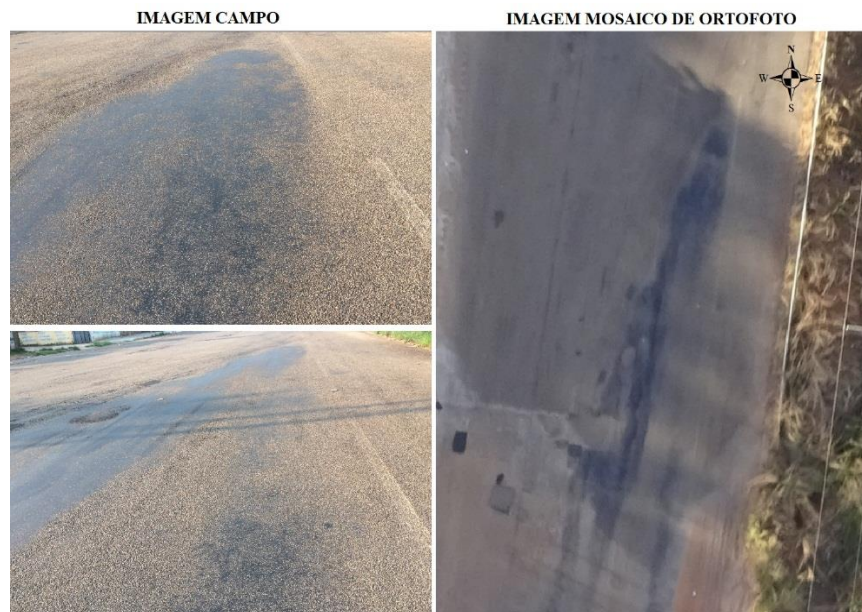
IMAGEM CAMPO   IMAGEM MOSAICO DE ORTOFOTO

Image 9. Exudation

4.2. Comparison of the compromised areas
In order to attest the reliability of the data collected through the observation of the images, a comparison was made between the area affected by the pathologies observed in the field and through the DSM of the TO-050. Image 10 exemplifies the process of data collection of an area deeply affected by road patching.

The usage of unmanned aerial vehicle (UAV) on mapping and identification
of superficial pathology on asphaltic pavement
D. Cardoso Parente, N. Carvalho Felix, A. Pessoa Picanço

Image 10. Deep pot hole patching

As a sample unit, 10 areas along the surface of the pavement were marked. The results thus obtained using both the mosaics and the in loco measurements, as well as, the absolute and percentage differences, are therefore organized in Chart 01.

Chart 01. Comparison among the number of identifiable patched areas

Image	In loco area (sqm)	DSM (sqm)	Difference between areas (sqm)	Percental difference (%)
1	9,61	9,49	0,12	1,25
2	6,68	6,58	0,10	1,50
3	10,35	10,20	0,15	1,45
4	0,26	0,23	0,03	11,54
5	0,70	0,68	0,02	2,86
6	0,96	0,91	0,05	5,21
7	0,98	0,92	0,06	6,12
8	0,77	0,73	0,04	5,19
9	0,32	0,29	0,03	9,37
10	5,70	5,55	0,25	4,38

The results show that the bigger the compromised area, the smaller the percentage differences observed in the orthomap are. Such a fact can be explained by the overlay of the same region being affected by a bigger number of images, in other words, bigger areas are shown in more overlapping images, increasing in that way the accuracy of the analyses.

The confidence margin is relevant and is equal to 95,43% of similarity, in average, taking into account that the results obtained were close the real value, which states to the accuracy of the DSM and of the geoprocessing software.

The usage of unmanned aerial vehicle (UAV) on mapping and identification
of superficial pathology on asphaltic pavement
169
D. Cardoso Parente, N. Carvalho Felix, A. Pessoa Picanço

4.3. Comparative analysis of the NIR and RGB images

Through the use of RGB images was possible to distinguish between the most recent and the oldest of the patches done to the road, by analyzing their colors and shapes; while through the analysis of the NIR images, the most recent patches are clearly evidenced for having a darker hue and better defined geometric form. Image 11 shows that older patched won't show up in the infrared images, having their color and shape concealed, and as a result it was harder to identify the right pathologies.

Image 11. Comparison between the images of the cameras RBG and NIR

Concerning the results, a significative difference can be ascertained, taking into consideration that some pathologic manifestations won't show in the NIR sensor, especially the ones that have a lighter hue like road patches, superficial deterioration and rutting.

5. CONCLUSIONS

The UAV system used in this research does not intend to replace the methodology endorsed by the engineering norms for the collection of information about pathologic manifestations on pavement, but add new tools to the method currently used, maximizing the information through by means of georeferenced images, which can be consulted at any moment, allowing the elucidation of uncertainties.

On the visual evaluation of the images obtained by the two sensors, NIR and RGB, for the identification of pathologic manifestation obtained via infrared sensor, it evidences the necessity of transferring details, for a precise identification of the flaws on the pavement. On the other hand, the images assembled with the three-color band are richer in details, making it easier to identify and to do a correct interpretation of the pathology.

Regarding the collection of areas which have been compromised by pathologies, it was observed that there is a low significance difference between the data collected via the mosaics generated that collected in the field.

The methodology shows, therefore, promising, since it presents quick results and can be used as an aid to identify flaws and to measure the quantity of work necessary to restore and maintain roads.

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