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Inspection of the technical condition of scaffolding using unmanned aerial

Abstract: Unmanned aerial vehicles (UAVs) are devices that are commonly used in various industries. Their availability makes them also a helpful tool for an engineer on a modern construction site. The article presents the possibility of using unmanned aerial vehicles for the inspection of the technical condition of the scaffolding with an area of approx. 1.500 m^2. As a result of the conducted UAV trials, a lot of valuable information was obtained, which was then subjected to a detailed analysis in order to identify critical elements of the scaffolding that posed a threat to work safety. An additional effect of the analysis is the developed point cloud, which shows the detailed geometry of the scaffolding and enables the analysis of the deformation of the structure.

Keywords: Unmanned aerial vehicle; Drone, Scaffolding; Construction industry; Occupational health and safety

Introduction

Construction scaffolding is a temporary structure, commonly used in the construction industry, whose main task is to ensure safe access to places located at height during construction works [3].

All construction scaffoldings must meet several formal and legal requirements necessary to ensure the safety of the structure. Currently, several dozen standards and about 30 legal acts related to scaffolding are in force in Poland [1, 3]. The above regulations imply, among others, that all construction scaffoldings should be: made, assembled, operated, and dismantled following the manufacturer's documentation or instructions (in the case of typical system scaffolding configurations) or according to an individual design (in other cases) [2]. Only a completely and properly assembled scaffolding with appropriate marking and grounding, which has been accepted by the site manager or an authorized person, may be used. Regulations [5] also require an additional inspection of the scaffolding, e.g. after: the occurrence of precipitation or strong wind, working breaks longer than 10 days, and at least once a month. A properly conducted inspection of the scaffolding should, in particular, allow for the identification of structural irregularities that may affect the correct and safe course of further construction works.

The previously available and possible form of inspection of the technical condition of the scaffolding involved the need for the inspector to enter the scaffolding. With the development of unmanned aerial vehicles, it becomes possible to use new technologies in the

control process. The purpose of the research and analyzes presented in the article is to indicate possible areas of application of unmanned aerial vehicles during the assessment of the technical condition of scaffoldings in the construction industry.

The subject of research and the tools used

The research and analysis of the use of drones to inspect the technical condition of construction scaffoldings were carried out in Wrocław, on the site of several construction sites of multi-family buildings. Each time during the inspection, an unmanned aerial vehicle from DJI, model Phantom 4 PRO V2.0, was used. The basic parameters of the device are presented in **Table 1**.

Tab. 1. Technical parameters of the device used during the inspection

Parameter	**Value**
Device weight (MTOM)	1,4 kg
Maximum flight time	up to 30 min (theoretical) up to 20-25 min (practical)
Maximum photo resolution	20 Mpix
Maximum video resolution	4K (60fps)

Performing an air operation with the use of an unmanned aerial vehicle is associated with the need to meet several requirements that are regulated by the relevant legal regulations [6]. Under the applicable regulations, drone operations near buildings are possible only in the "special" category, according to the "standard scenario" (STS), which presents the requirements for drones and maximum flight parameters, including height and distance. In addition, the pilot of an unmanned aerial vehicle operating in the "special" category is required to have appropriate authorizations and should be registered in the system of unmanned aerial vehicle system operators.

It should also be noted that one of the most important elements that may significantly affect the possibility of performing an air operation and its safety are the limitations resulting from the construction of the airspace structure..

Evaluation of the technical condition of construction scaffolding - a case study

Below is an exemplary course of inspection of the technical condition of one of the construction scaffoldings in Wrocław. The area of the analyzed system scaffolding was approx. 1,500 m^2. All critical elements of the scaffolding structure were inspected, such as: connections, braces, securing elements, and others. The inspection of the scaffolding with the use of a drone significantly shortened its duration to about 30 minutes and allowed to obtain, in a safe manner, without threats and near-accident situations, extensive photographic and video material.

For example, Figure **1** shows a photo taken with a drone camera - a detail where you can see the connection of the working platform and braces with the main frame.

1. View of the scaffolding construction detail - connection

The acquired extensive photo and video material allowed for a detailed assessment of the scaffolding geometry and analysis of the components of the scaffolding without the need to climb onto the tested scaffolding. The assessment of the geometry and technical condition of the scaffoldings using the collected test material can be performed both in terms of quantity (e.g. verification of the completeness of the structure components) and qualitative aspect (e.g. identification of damage) in terms of, among others: correct assembly of braces, railings and boards curbs (figure **2**) and scaffolding equipment elements, e.g. winches (figure **3**).

2. View of the scaffold bracing perpendicular

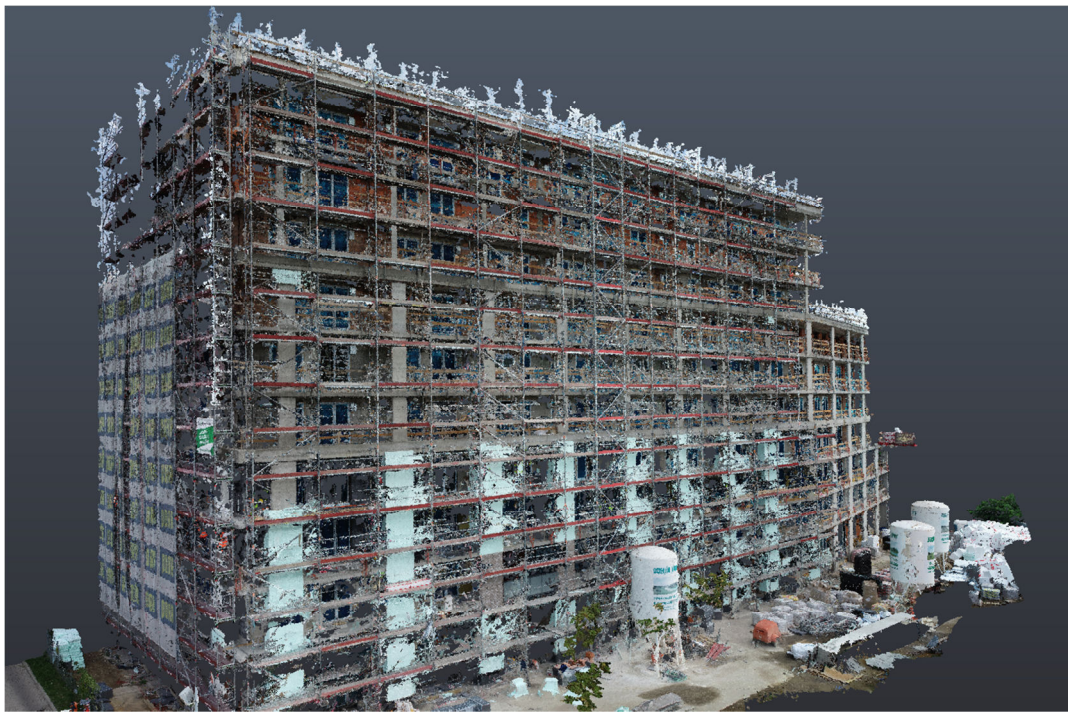
3. View of the winch

The drone used during the inspection also made it possible to efficiently locate structural damage, which may be a source of danger to scaffolding users. An example of such damage may be a bent handrail (figure **4**) or a cracked curb board (figure **5**).

4. View of the damaged handrail

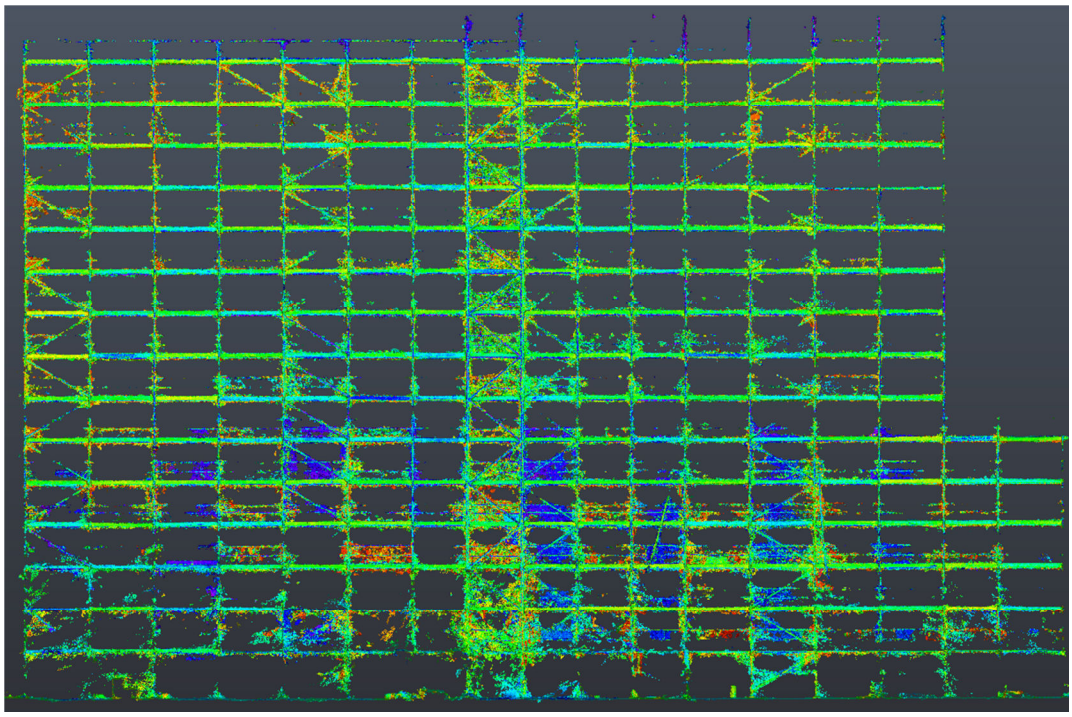
5. View of the damaged curb board

The photos taken during the raid, at a distance of approx. 10-15 m from the scaffolding, allowed for the development of a point cloud of the structure. To develop it, the photogrammetry technique was used, which allows obtaining a spatial representation of real objects based on photos [4] and Autodesk's ReCap software. The developed point cloud (Figure **6**) is characterized by a high density of points (total number of points: 104,306,967), where each point is assigned coordinates in 3-dimensional space (X, Y, Z) and color (described with RGB coordinates).



6. General view of the developed point cloud

The analysis of the developed point cloud allows e.g. for the identification of the static scheme of the structure and the measurement of possible deformations (Figure **7**).



7. View of the external scaffolding – point cloud

Summary

The analysis of the use of unmanned aerial vehicles during the assessment of the technical condition of construction scaffolding allowed to identify the most important benefits and limitations resulting from the use of unmanned aerial vehicles as a tool supporting control. The most important of them are listed in **table 2**.

Tab. 2. Advantages and limitations resulting from the use of an unmanned aerial vehicle to inspect construction scaffoldings

Advantages	**Limitations**
• Quick acquisition of high-resolution photographic and video material, • Significant reduction of the time necessary to inspect the technical condition of the scaffolding compared to traditional methods, • The ability to reach hard-to-reach parts of the scaffolding - e.g. located at a height, • Reducing the risk for people entering the scaffolding in the absence of certainty as to the stability of the scaffolding, • Locating minor defects in the scaffolding structure that may pose a threat to work safety.	• Difficult access to the scaffolding elements located from the side of the building facade, • The need to have appropriate qualifications to perform air operations with the use of drones, • Dependence of the ability to perform flights on terrain and weather conditions (e.g. precipitation or wind speed above 10 m/s in most UAVs significantly hinders or prevents the performance of the flight), • The need to comply with airspace restrictions,

Summary
The obligation to inspect the technical condition of construction scaffolding is a prerequisite for its safe use. As shown in the article, unmanned aerial vehicles are a tool supporting control and contributing to a significant reduction in the time necessary to carry it out. Drones enable the quick and safe collection of detailed photographic and high-resolution video material without having to climb the scaffolding. Such functionality of drones contributes to a significant reduction in the exposure of employees performing inspections to risk factors occurring on the construction site, in particular on construction scaffolding.

In addition, properly collected photographic material enables a visual assessment of the technical condition of the scaffolding, checking the completeness of all components and early detection of damage that may pose a threat to safe operation. In addition, using the appropriate computer software, it is possible to further process the collected material. This enables e.g. development of the so-called cloud of points of the tested scaffolding, which presents the actual geometry of the scaffolding in three-dimensional space (3D).

However, it should be remembered that operations with the use of drones can be performed by persons with appropriate qualifications, and the correct and safe course of the operation is affected by several factors related to, among others, terrain and weather conditions.

Source materials

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