SAFETY OF BUILDING CRITICAL INFRASTRUCTURES AND TERRITORIES

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ANALYSIS OF EXISTING DOMESTIC AND INTERNATIONAL PRACTICES OF THE UNMANNED AERIAL VEHICLES' USING IN CONSTRUCTION AND SOME PROSPECTS FOR THEIR USING IN THE MIDDLE URALS

Abstract. The using of unmanned aerial vehicles (UAVs) is gaining popularity around the world in lots of different spheres of life, the construction industry is no exception. The dynamics of the development of the UAV's using in Russia is considered. The practice of using drones in various areas of construction is presented: topographical survey, construction control, monitoring of the technical condition of the building. The prospects for the UAV's using in the Middle Urals are reviewed.

Keywords: unmanned aerial vehicles, topographic survey, construction control, monitoring of the building technical condition, drone

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АНАЛИЗ СУЩЕСТВУЮЩЕЙ ОТЕЧЕСТВЕННОЙ И МЕЖДУНАРОДНОЙ ПРАКТИКИ ИСПОЛЬЗОВАНИЯ БЕСПИЛОТНЫХ ЛЕТАТЕЛЬНЫХ АППАРАТОВ В СТРОИТЕЛЬСТВЕ И НЕКОТОРЫХ ПЕРСПЕКТИВ ИХ ИСПОЛЬЗОВАНИЯ НА СРЕДНЕМ УРАЛЕ

Аннотация. Использование беспилотных летательных аппаратов (БПЛА) набирает популярность во всем мире в самых разных сферах жизни, строительная отрасль не исключение. Рассмотрена динамика развития использования БПЛА в России. Представлена практика использования дронов в различных областях строительства: топографическая съемка, строительный контроль, мониторинг технического состояния здания. Рассмотрены перспективы использования БПЛА на Среднем Урале.

Ключевые слова: беспилотные аппараты, топографическая съемка, строительный контроль, мониторинг технического состояния здания, дрон

Introduction

The sphere of construction in Russia is developing rapidly at the present time: the concept of smart cities is being introduced, unique industrial and civil objects are being built.

Civil engineers have always been tasked with the construction buildings and structures at the lowest economic cost and with a high rate of construction, at the same time creating conditions for the safe stay of people in these buildings. For these purpose, modern technologies of construction production are actively used; different innovative building materials are created; software systems, that allow to accurately design new facilities and allow monitoring of building structures of these objects in the future, are introduced; methods of safe construction are promoted.

One of the innovative implementations in the field of construction is the using of un-manned aerial vehicles (UAVs) at various stages of construction buildings and structures.

This article describes the examples of the UAV's using in construction all over the world, on the territory of the Russian Federation, as well as it describes the prospects of the UAV's using in the Middle Urals.

Dynamics of the UAV's using in Russia

There are about 190 companies in the Russian market, which carry out their activities in the field of application of UAV according to the research "Market of drones in Russia and in the world, 2017", conducted by J'son & Partners Consulting with the support of the Association AERONET [1]. It is also noted that the potential using of UAVs in Russia is significant [2].

The main directions of development the drone's using in Russia are aerial photography and cartography; monitoring of objects, agriculture; search and rescue of people in distress; transportation. There is a histogram in the Fig. 1, which is showing the growth of the UAV market in various spheres of life by 2020–2030 according to the AERONET Association [3]. It should be noted that the UAV's using in the field of remote sensing and monitoring, including mapping and inspection of ground infrastructure (industrial, transport, civil, etc.), will increase by 2025 by 85 % according to the specialists of the Association AERONET.

According to the histogram (in Fig. 1) you can see, that one of the promising areas of UAV application is remote sensing and monitoring, including the survey of industrial and civil construction, mapping, surveying. In addition, according to experts of leading companies in the field of the UAV's using, promising niches of the UAV's using in Russia, together with monitoring in agriculture and the creation of a single electronic cartographic basis, is the creation of "digital copies" of smart cities, the identification of heat loss, monitoring of extended infrastructure facilities, monitoring of construction [1].

The UAV's using for earthwork

There are important initial stages of the entire production work in construction: geodetic works and surveying the area of the building site. Competent performance of these works is the basis of all design process. It is necessary to complete all phases of work quickly in the conditions of the modern pace of life and construction. However, the speed must be ensured without loss of quality. Information technologies (IT) come to the aid of an engineer in solving this problem. Namely, the cumulative using of an UAV and special software for surveying the terrain with the purpose of generating a map, as well as a 3D model of the design site and counting the amount of work. The system collects material in the form of photographs, video and geodata (coordinates of the terrain with reference to the global coordinate system, elevations of points) automatically. Then the information is processed using special software. The UAVs can have special equipment: cameras, video cameras, heat sensors, GPS equipment, lidar sensors to prevent collisions with trees, towers, etc. The result of this work is flat maps, orthophoto maps, spatial terrain models.

For example, Autodesk, together with 3D Robotics and Kimly-Horn, developed the program bundle Site Scan back in 2016. The Denver County terrain model was created thanks to their development using UAVs. Nowadays, developers are closer to the goal of reducing the time of all work on the collection and processing of information to 24 hours.

For comparison, such work is carried out by professional organizations for 1–3 days [4], from 3 days with a land area of 2500 m^2 [5]. At the same time, it is worth noting that these works are carried out by a team of several workers. It leads to an increase in the cost of work and the likelihood of human error. A definite advantage of UAV is no obstacles, such as hard-to-reach places of relief or restriction of movement in the form of reservoirs. As a result, the movement of a person over rough terrain is excluded, the risk of injury is reduced, the safety of work is getting to increase.

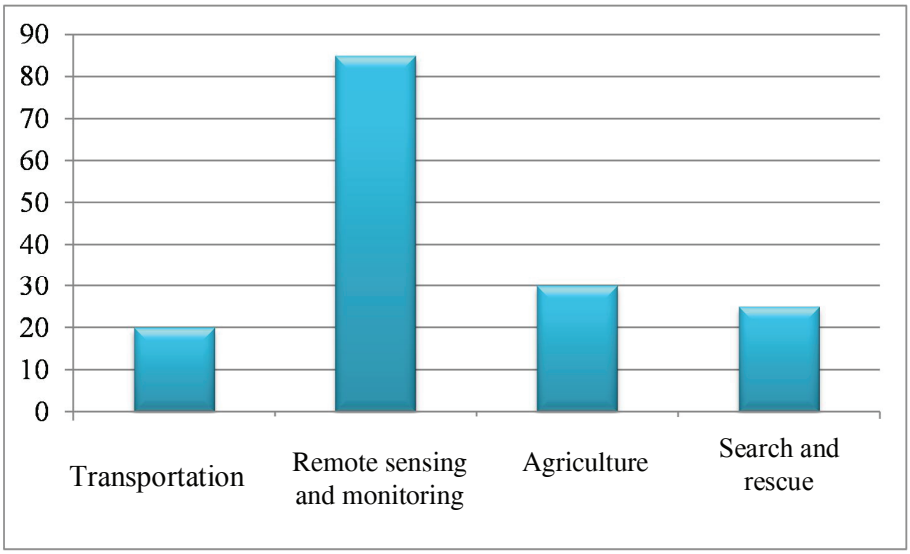

Fig. 1. The growth of UAV's market (in %) in various spheres of life by 2020–2030 in the Russian Federation

Fig. 2. Aerial photography

Fig. 3. Orthophoto map

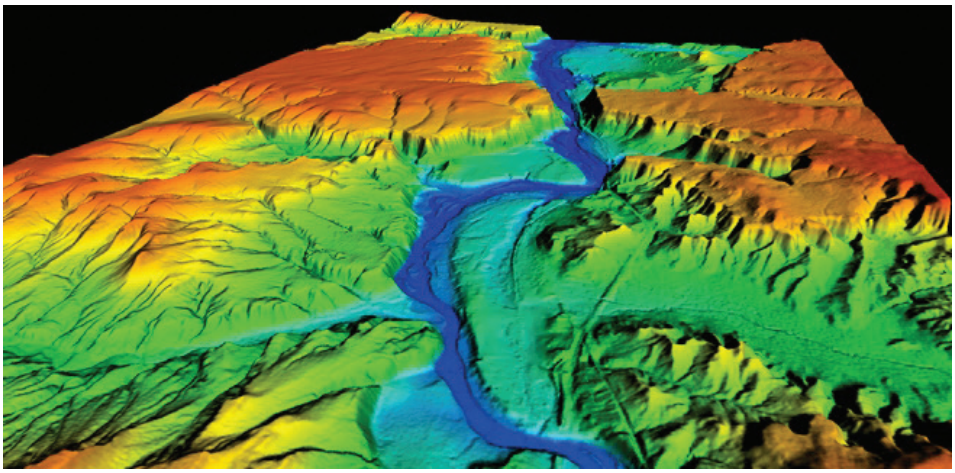

Fig. 4. Topographic digital model

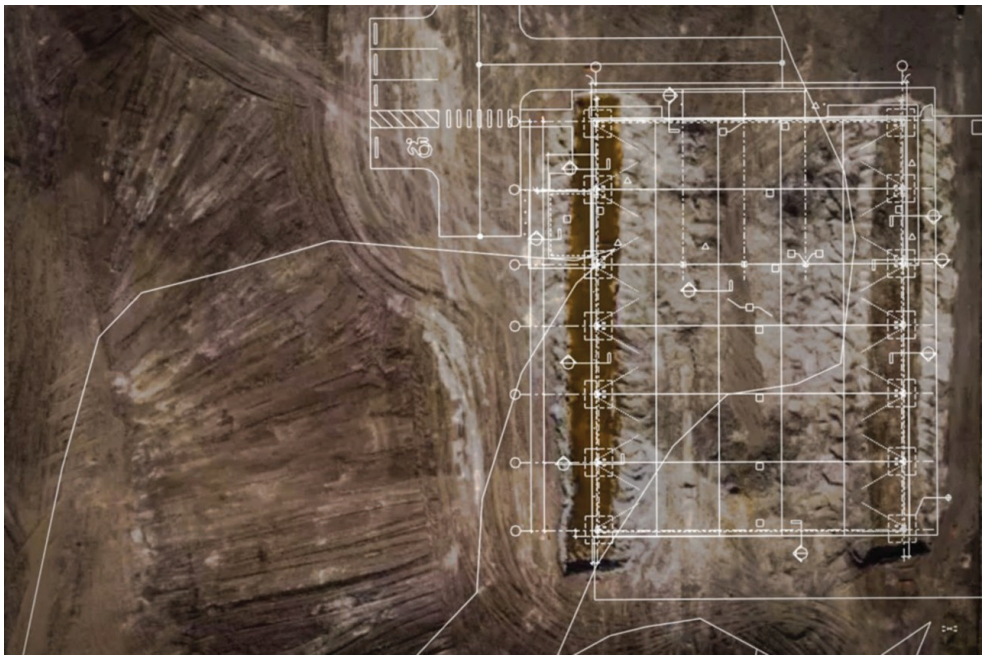

Fig. 5. The Site Scan result

Construction monitoring

Inspection of the construction process is necessary to obtain a quality product after completion of work. It is possible to lose sight of the mistakes, made by workers as for traditional work methods. IT can also help specialists in this area of construction. It is possible to track the construction progress in real time thank for UAVs that is equipped with video cameras. The data from cameras are processed by neural networks trained on an array of data on the competent performance of various construction works, on the competent organization of construction and storage of materials. In addition, it is capable to detect inadequate behavior of people on the construction site, vandal actions or the entry of outsiders into a closed area. For example, the presentation of Kespry UAV and software from NVIDIA hosted in 2016, the United States [6]. Their UAVs with special software are capable of recognizing building materials warehouses and construction equipment. As a result, a conclusion about work stoppages can be drawn and the work schedule can be edited after the recognition of construction equipment at the site. That will save time and money.

Another example is Brassfield and Gorrie (USA) [7]. Their UAVs are necessary for optimizing the construction process, namely, they can track the progress of construction, evaluate the work performed and compare the real data with the construction plan (scope of work, elevation marks, etc.).

The sequence of results of the work performed can be seen in Figs. 7–10. As a result of the flight, a three-dimensional model is compiled that shows information on the distribution of elevations of the terrain. Then, a ther-

Fig. 6. Process of inspection by UAV

mal map of the terrain is created. After that the thermal map of the area is compared with the construction plan and the results of the discrepancy between the planned and real elevations are displayed: the zones marked in green coincide with the plan, the blue ones are completed below planned, the pink ones are completed above planned.

Fig. 7. The camera flyby result

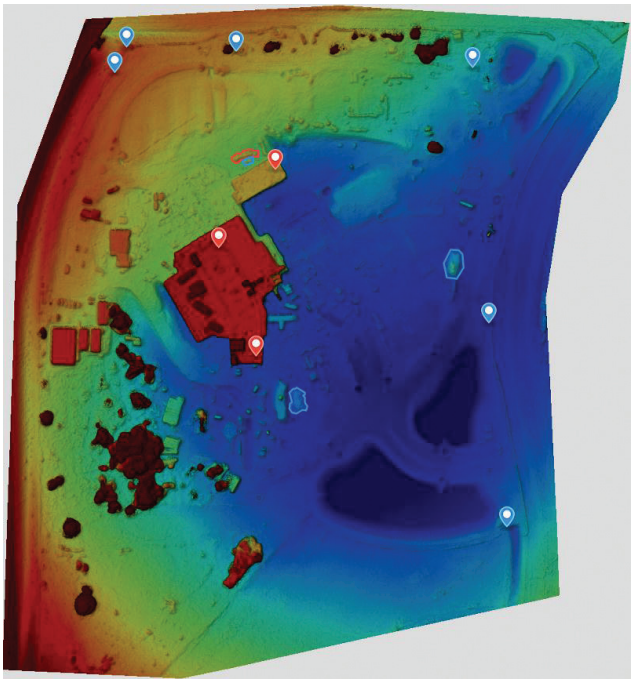

Fig. 8. The orthosomal map

The UAVs using during the operation of the object

In connection with foregoing this type of PB is not suitable for using as the premises for wide range of medical technologies. The arrangement of operational facilities is also impossible, since the supporting frame of the building and the enclosing structures are susceptible to increased bactericidal effects, as well as purulent and exudate absorption, which is not permissible, since the operating unit must have a special class of purity. Still, this type of PB can be used as a pharmacy or a temporary facility for FAP, temporary medical units of short purposes, as well as emergency medical services (an ambulance or emergency room).

According to Code of Practice 255.1325800.2016 "Buildings and structures. Operating rule. Basic provisions", actions for control of the technical condition of the building (structure) for maintain its performance and serviceability should be provided during the operation of the object. In addition, unique buildings and structures are subject to increased requirements, so they are needed a device for continuous monitoring of the technical condition of the bases and building structures [8]. In this regard, operating costs typically account for an average of 75 % of total costs [9].

We can make sure that the use of UAVs is economical and promising during the operation of the building, namely during the inspection of structures.

Often, builders arrange scaffolding and various auxiliary sites for direct access to these structures during the visual inspection of structures and to perform measurements of their geometric parameters which can lead to temporary restrictions of work for example in an industrial building. Any stop of the technological process together with the temporary cessation of operation of the building leads to economic losses. It should be noted that a mandatory device of safe accessories accompanies all works on inspection and measurement of building structures carried out at a height of more than 3 m for safety reasons which requires additional costs [10].

Therefore, of the UAVs using for inspection of building structures for defects allows not only to support the continuity of technological processes in the building, but also helps to reduce the risk of potential hazards faced by builders in the survey of high-rise buildings.

Along with high-rise objects, the UAV's using simplifies the monitoring of large-span structures, such as bridges. Since the use of UAVs for visual inspection (detailed aerial photography and subsequent photogrammetric processing of images) does not require the cessation of movement on the bridge, so the movement of vehicles and pedestrians on the bridge is safe. In addition, the use of UAVs for bridge monitoring is economically feasible. The government of the city of West Sussex in the UK, together with Balfour Beatty Living Places, used UAVs for assess the condition of two bridges: Swan Bridge in

Fig. 9. The three-dimensional information model of the construction site

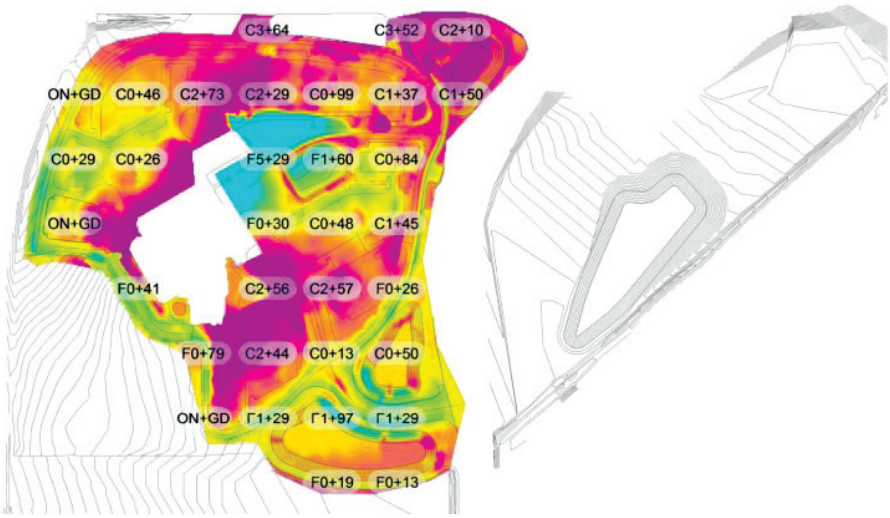

Fig. 10. The result of the comparison of the thermal map of the area and the construction plan for the project

Pulborough and Adur Ferry Bridge in Shoreham-By-Sea, which resulted in cost savings of $ 8,000 compared to traditional survey methods [11].

Russian scientists V. V. Korenev, N. S. Orlova proved a significant advantage of the use of UAVs in the inspection of buildings, and during inspecting the facades of high-rise buildings and identifying their defects. Compared with traditional methods, orthophoto plan, created by the results of photography, allows you to identify defects in hard-to-reach places, as well as allows for accurate calculation of materials for the repair of local areas of the façade [12].

We give an example of a three-dimensional defect map in Fig. 11 that was obtained using a drone equipped with a special camera and thermal imager. This picture displayed in the GIS program "Sputnik" was obtained thanks to a specially developed method of the group of companies GEOSCAN [13]. Note, that the places and types of defects of buildings in the pictures are clearly visible.

Prospects of the UAVs using in construction in the Middle Urals

There was an increase the number of cases of roof collapses of buildings in Russia in recent years, mainly due to violations of the rules of operation of the roof due to exceeding the maximum snow load. So, the roof of the production building "The machine-building plant named after M. I. Kalinin" collapsed in the winter of 2016 in Ekaterinburg. The cause of the collapse was the

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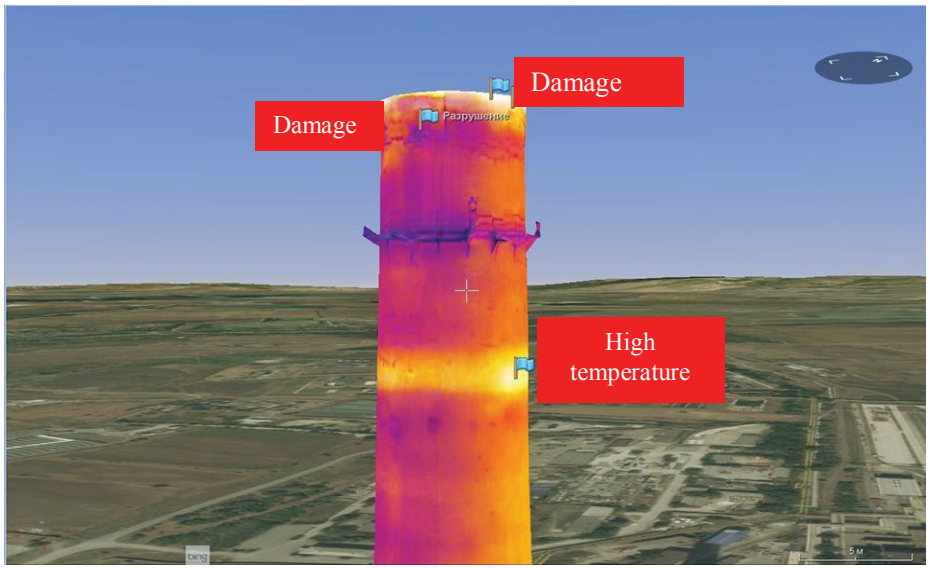

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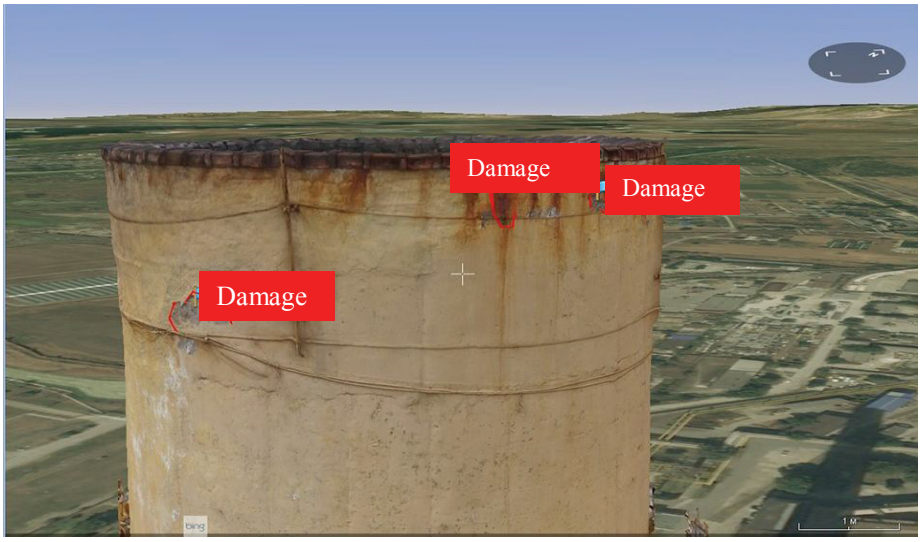

Fig. 11. Three-dimensional defect map

snow, that was accumulated after heavy snowfall. As a result of the collapse, 4 people were killed, and 14 people were injured. The main reason for such incidents is a violation of the rules of operation of the roof, namely the untimely cleaning of the roof of snow. For various reasons, the building management function allows the accumulation of snow cover on the roof of buildings, as a result, its total weight exceeds the maximum snow load and there is a loss of bearing capacity of the coating structures.

In this regard, there is a need for continuous remote monitoring of the weight of snow cover on the roof of buildings, that is allowing timely monitoring of the maximum snow load on the roof. The UAVs using is promising for the creation of such monitoring. So, it is possible to determine the weight of the snow cover (and its other parameters) remotely, excluding the direct presence of people on the surface of the building. The using of UAVs allows to obtain data on the weight of snow cover on the roof of the building. Special maps of the spatial distribution of the weight of the snow cover on the roof can be made after the data processing. These maps will include areas of snow accumulation with a load exceeding the limit. The staff of the building management function, using such card, will be able to receive actual information about distribution of snow loading on the roof and to make decisions on cleaning of a roof of snow in time, without allowing an over load of building designs of a covering.

It is also necessary to carry out a technical inspection of the coating structures in order to identify places that need to be repaired in the summer period. You can inspect the coating from a height several times faster compared to traditional survey methods thank for UAVs. After collecting video and photo materials about the con-

dition of the roof, it is possible to process the data and make a conclusion about the need for repairs, as well as to make a list of these works automatically. It is possible to identify defects in the coating more quickly and create a safe environment for the operation of buildings thank for UAVs.

Conclusions

In the article there was said the UAV's using at all stages of construction: the preparatory stage, monitoring the progress of construction, the inspection during operation, the detection of defects. Also, the examples of actually working technologies in the world was mentioned and prospects for the using of developments in Russia and, in particular, in the Middle Urals, are considered.

The using of UAV at the construction site is caused by the need to automate and optimize many processes. Such an improvement in construction technologies and the monitoring of their quality performance leads to cumulative savings of money and time resources without loss of quality. In addition, the level of safety is getting to increase regardless of the construction stage where the UAV will be used. Of course, technologies are costly at the initial stage. At the same time, they are a contribution to the future, where profits will increase due to saving time, the possibility of performing more work on more objects without expanding the staff of specialists. And undoubtedly, the using of UAV at various stages of the life of a construction object is a timely solution of problems: both the monitoring of the quality of construction processes and the detection of defects in building structures during operation.

Thus, the UAV's using for visual quality control of construction processes is necessary to ensure high quality products in the modern conditions of the construction market.

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