Aerodynamic features of buildings with runways unit

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Abstract. Currently, opportunities are being developed and are being considered for using flying taxis in large cities due to promising types of air transport (Flying cars, passenger drones). In the second half of the twentieth century, projects for the development of helicopter transport were developed in the UK and the USA. Within the framework of this project, projects for heliports and buildings that interact with helicopter transport were developed in the UK. This experience is very important in the design of buildings with a runway unit, interacting with advanced air transport. Based on an analysis of projects in the UK and the USA, the authors developed experimental aerodynamic schemes of buildings with a landing unit. These projects were tested in the Virtual Wind Tunnel and implemented with the recommendations received by the authors at TsAGI (Central Institute of Aerohydrodynamics). In architectural design of buildings interacting with air transport, aerodynamics is the most important tool for shaping the spatial and compositional solutions of architectural objects.

1. Introduction
XX century gave the world a lot of amazing discoveries and developments, including a flying car. Understanding of the need for decisive action in the organization of the transport network of the city turned the eyes of architects and engineers in the direction of urban air transport since the middle of the XX century. Ideas of flights in the city are reflected in the works of architects and artists of science fiction, such as "Einem Partnership", Klaus Brugle, Arthur Badebo and others. The futuristic projects of the future depict an active symbiosis of the city with all modes of transport including air transport which is emphasized. By the middle of the XX century, these ideas began to take shape thanks to the appearance of the first civilian serial helicopters for air traffic in London and projects of buildings with large helipads [1]. Large-scale helicopter routes between cities and the nearest countries were planned. However, these projects did not allow to continue in this direction active development of air transport because of technical shortcomings of helicopters of that time [2, 3, 4].

The development of technology and the increase in the number of different vehicles has led to a significant complication of the transport infrastructure such as major highways, interchanges, tunnels and parking lots, as well as some changes in the design of buildings, which often include underground parking and helipads. However, the existing design methods of designing objects in large cities no longer meet the requirements of modern life in the city with a rapid increase in transport per capita.

The current problems force the developers of vehicles to create projects of new modes of transport, allowing to increase transport mobility and efficiency in the city, as well as to solve environmental problems through the use of alternative energy sources [5, 6]. Thus, it generates a new round in the development of urban air transport, which has a serious chance of success due to major breakthroughs in engineering, automation and electronics. Currently, helicopter transport in the megacities of the world is developing rapidly, and passenger traffic is increasing every year. It is very likely that helicopters, and later passenger drones, will occupy a large segment in the urban transport system [7].
The promising air transport includes passenger drones of various designs, for example, a passenger drone from Airbus. It should be noted that this group of transport has a similar mechanics of flight with helicopters ‘figure 1’ [8, 9]. Therefore, it is necessary to study the main features and developments in the design of buildings with helipads. It will help to make the most accurate forecast of how the architecture of buildings can change, interacting with urban advanced air transport. Usually in modern studies on the aerodynamics of buildings with a helipad, the authors consider narrow technological and engineering problems [10]. However, to create form-building methods for buildings with a helipad, research in architectural aerodynamics is necessary. This study offers architects some methods that allow the design of buildings with helipads not to lose the architectural expressiveness of the author's intention [11].

Figure 1. Prototypes of modern flying cars and passenger drones.

In addition to urban ideas and concepts, appropriate principles should be developed for the formation of architectural objects with a runway unit. These principles will allow to contact with a new type of transport. The existing helipads are not ready to receive such transport, they often do not have a control tower and space for temporary storage of aircraft. Also, they are not adapted for use without prior preparation [12]. New types of buildings can be created according to the "aircraft carrier" principle. "Aircraft carrier" is a kind of floating city with an airfield, which ideally combines these two functions. Buildings should have special landing platforms: with markings, landing lights and anti-icing elements.

2. Materials and methods
Airflow modeling was computed using Autodesk's Flow Design computer program, which simulates airflow around architectural concepts. This is necessary to test ideas early in the development cycle. This virtual wind tunnel software is intended for designers and architects. The study presents forms for buildings with a helipad were obtained experimentally. The main purpose of experiments with the shape of the building, to achieve a steady air flow in the area of the helipad. The main purpose of experiments with the shape of the building is to achieve a stationary air flow in the area of the helipad for buildings with a runway unit. The forms obtained by the authors were analyzed for changes in the internal layout of the building with the runway unit. For the analysis, the authors created sketchy 3D models with functional zoning of buildings. Images of the air flow around the buildings were obtained by the authors in the Autodesk "Flow Design" computer program.

Air transport has fairly high safety requirements, not only for operation, but also for the infrastructure with which it interacts. One of the most important conditions for the safe use of a new type of air transport will be the requirements for the aerodynamics of buildings. There are several types of cities: "plains", "hills" and "hollows", which corresponds to different heights of urban development and the terrain [13, 14, 15]. These types of building directly affect the height of the landing pads (consoles, roofs, courtyard spaces) in urban areas and their location on the master plan of the city in terms of the wind rose. These parameters are necessary to create favorable aerodynamic conditions above the landing pads in the city.
For the experiments were selected the main types of aerodynamic schemes of buildings on which helicopter pads can be located. In the course of the experiment, 9 models of buildings were blown through the virtual wind tunnel: a cylindrical, rectangular tower type, a cavity (rectangular with a courtyard), an open courtyard cavity, T-shaped in plan, L-shaped in plan, C-shaped in plan, trefoil, H-shaped in plan, cruciform in plan ‘figure 3’, ‘figure 4’. The dimensions of the models were given as close as possible to the overall dimensions.

![Visualization of the air flow lines demonstrates a very successful aerodynamic design of the building due to the absence of turbulent vortices over the landing pad.](image)

**Figure 2.** Visualization of the air flow lines demonstrates a very successful aerodynamic design of the building due to the absence of turbulent vortices over the landing pad.

Pilkington's Glass Age Development Committee Visualization is made in the program Flow design. The air flow velocity is 10 m/s.

![Figure 3. Airflow around tower-type buildings.](image)

**Figure 3.** Airflow around tower-type buildings.

All models of buildings have a height of 30 meters and dimensions in the plan in the range from 30-50 meters to 60-80 meters, depending on the configuration of the floor plan. The experiment revealed relatively similar nature of the wind flow over all the buildings except the cavities. When the air flow around the buildings forms several characteristic swirls on the building and the same aerodynamic footprint. The air escaping from the roof of the building is called a vortex layer. Under this layer formed outgoing turbulence. The aerodynamic footprint in the plan is a vortex track in the form of whirlwinds, diverging in a checkerboard pattern. On buildings with such aerodynamic characteristics, landing sites are usually installed on the roof in a stationary air flow.

The cavity has favorable conditions for the landing of an aircraft due to the formation of a steady vortex inside the cavity (inner courtyard) and low air velocity. Experiments have shown that the landing site should be placed in the center of the vortex, where the air flow is minimal. The experiments also revealed the movement of the vortex in the direction of the wind to the opposite wall of the cavern and the appearance of the second vortex, provided that the size of the cavern courtyard exceeds 90 meters. When the air flow rate is from 7 to 10 m / s, the speed of the air flow in the yard is...
about 3-4 m/s. In square in plan yard spaces with a size of more than 70-90 meters, a vortex moves in the direction of the air flow ‘figure 5’.

| Building Type          | Scheme of Flow Lines in the Plan, Air Velocity 10 m/s | Scheme of Current Lines in the Vertical Plane, Air Velocity 10 m/s | Visualization of Air Flow Paths of Particles, Air Velocity 10 m/s |
|------------------------|--------------------------------------------------------|------------------------------------------------------------------|------------------------------------------------------------------|
| L-shaped building      | ![Image](image1.png)                                   | ![Image](image2.png)                                           | ![Image](image3.png)                                           |
| C-shaped building      | ![Image](image4.png)                                   | ![Image](image5.png)                                           | ![Image](image6.png)                                           |
| Y-shaped building      | ![Image](image7.png)                                   | ![Image](image8.png)                                           | ![Image](image9.png)                                           |
| H-shaped building      | ![Image](image10.png)                                  | ![Image](image11.png)                                          | ![Image](image12.png)                                          |
| Building is a cross    | ![Image](image13.png)                                  | ![Image](image14.png)                                          | ![Image](image15.png)                                          |

**Figure 4.** Airflow around the most common forms of buildings.

![Image](image16.png)

**Figure 5.** The movement of the vortex in the direction of the air flow inside the cavity of more than 90 meters. In the caverns with a courtyard up to 70 meters there is a stationary whirlwind.
3. Results
Experiments were carried out with typical forms of buildings of prismatic configuration and the American heliport "Port Authority". Was modeled several aerodynamic designs of buildings with favorable aerodynamic regime. Various forms of the building were applied.

The building with the "inverted wing". The most common version of the location of landing pads - the roof. This is the highest point for landing among the surrounding buildings, which can be relatively easy to land.

The air flow of such buildings is not stationary, because the air flows on the leeward side of the building are alternately separated. The angular value between the landing pad and the flow disruption depends on the air flow rate and the time from the beginning of the blowing, as well as the height of the building.

To ensure that the landing pad is always in a stationary air flow, it can be placed on a streamlined platform and raised above the main body of the building. The air becomes freely circulated to the platform with two sides. The platform has a profile resembling the profile of an inverted wing.

The building step shape allows landing on the roof due to the stationary air flow over the roof. Air flow failure is observed only at the edge of the roof from the incoming air flow. This effect is provided by the stepped structure of the facade, as it slows the upward flow from the windward side of the building. This prevents the flow from the edge of the roof from the incoming air flow. This solution provides a steady wind over the landing pads. However, it has its limitations for landing aircraft due to the maximum possible wind speeds for landing on the building.

Caverns or yard spaces. Wind flows move over the roofs of buildings in cities on the plains, where the buildings are about the same height. They do not create disturbances in the airspace along the streets, as they coincide with the direction of the wind. The cavern has the most favorable conditions for landing due to the formation of a stationary air flow inside it and a low speed of air movement in it. Experiments have shown that the landing pad should be placed in the center of the vortex, where the movement of the air flow is minimal. Thus, the motion of particles forms a stationary vortex flow. The speed here is much lower than above the roof of the building. Experiments were carried out on computer models at different air flow rates. At a wind speed of 10 m/s, the movement of particles inside the cavity is 3-4 m/s, and at a wind speed of 15 m/s, the movement of particles inside the cavity is 5-6 m/s. The experimental results show that the air velocity inside the cavity is usually 3 times lower than above the roofs.

The main features of buildings with a landing pad are as follows: it has three options for the location of the landing pads on the building: at the level of the roof, on the console, in the cavern. There is a need to create an optimal aerodynamic regime over the runways to ensure safety during take-off and landing. The runway unit has a set of main and auxiliary premises. It has special damping structures on the runways. It has lighting, meteorological and navigation equipment ‘figure 6’.

4. Discussion
The principles of formation of buildings with the runway unit were developed. They showed a great potential of architectural and planning diversity of buildings of a new type. Three schematic diagrams of buildings were made in the Autodesk Flow Design program. They differ in the location of the runway unit. This affects the space-planning decisions of the project. However, it should be noted that the dimensions of the buildings of these concepts may vary depending on the specifics of the project and its location in the building. The illustrations show the methods of forming buildings with a runway unit, which will require more detailed study.

Buildings with a console location of the runway unit can have three options for the location of consoles. First, the fan location, which is most suitable for tower-type buildings. In this case, the
consoles can be in the same level around the perimeter of the building. Secondly, the consoles can be located at different heights. This option is suitable for multifunctional high-rise buildings, which will allow quick access to the necessary functional area of the tower, and landing pads will be in the aerodynamic shadow of the tower. In these two variants, the runway unit is located in the body of the building, and the landing pads are consoles. In the third variant, the runway unit is a large console that extends beyond the building. This option is suitable for buildings of any configuration.

**Figure 6.** Experimental projects of building shapes to create a favorable aerodynamic regime over the helipad.

Buildings with a runway unit on the roof also have three schemes. The building with a terraced location of the runway units is suitable for long buildings with different functional purpose. In the building "aircraft carrier" runway unit is located on two parts of buildings. The roof of such a building is divided into two parts for takeoff and landing. On the roof there are Islands with entrance groups and elevator halls, a control tower and lifts for air transport. This building is most suitable for emergency services, fire protection, medical centers, which are located in a dense urban area. This type of building will allow in emergency situations to send and receive a large number of aircraft per minute. The building with a raised runway unit above the main building is designed for cities with one high-rise buildings. This is optimal for aerodynamic qualities and the most convenient for the location of the runway unit for landing.

Two principles have been developed for buildings with a runway unit in the cavern: the first - the runway unit is located in the courtyard of the building. The second - the landing pads of the unit are deepened in the caverns on the roof of the building. This location is suitable for low-rise buildings, such as transport hubs, shopping centers, technology parks ‘figure 7’.

The basic principles of planning decisions were developed. A set of rooms and functional areas for the runway unit has been given in these principles. The runway unit consists of several functional zones: landing pad, pad to lift-off area for pre-training, entry gateway for transportation, parking, vertical transportation, aircraft. In these schemes, some variations may be used depending on the shape and type of building, such as departure and arrival areas. They can be separated or combined to carry the character. The runway unit is separated by technical floors and fire compartments. The unit has its own entrance groups, which include security posts, checkpoints, reception desks, waiting areas, etc., which are located in the departure and arrival areas.
Figure 7. Schemes of architectural forms of buildings with optimal aerodynamic properties (experimental building designs with a runway unit).

The buildings are interacting with air transport will change in comparison with buildings with a helipad. First, the shape of the building will be dictated by aerodynamic calculations based on aerodynamic analysis. It will be taking into account the individual characteristics of the surrounding buildings and terrain. Secondly, the internal structure of the building will change, as it will become important for regular flights of promising air transport. The building has a number of facilities and engineering solutions that will allow you to efficiently and safely take and send advanced air transport and provide high capacity for passengers. The Airbus transport system takes into account the principle of hybridization of the aircraft with the car in the building interacting with the perspective air transport. In this building there are vertical communications that can provide communication with the street and road network of the city.

Thirdly, it is necessary to organize the storage and maintenance of aircraft. The above features of buildings interacting with advanced air transport can be combined into one "unit", which is built into the structure of the building. Such a "unit" in the building makes the building look like a heliport or aircraft carrier, where the flight deck is the roof, console or cavern, and auxiliary functions are located inside the building. Based on this, you can define a new type of building – a building with a runway unit. The runway unit in the building is a complex of premises and engineering measures providing reception, dispatch, basing of aircraft with a system of vertical take-off and landing and air transportation services [16].

5. Conclusion
The experiments were considered: building with an elevated helipad on the roof, the building is a stepped form and the building with a helipad in the courtyard space. This is necessary in order to create the best aerodynamic conditions over the runways. In these experiments, form-generating methods were used, which allow to organize the optimal aerodynamic characteristics above the helipad. Also, these methods allow architects and designers to create the expressive shape of a building. Consequently, when designing buildings with a runway unit, an architect can use the results of these experiments to create the most expressive architectural appearance of the building. Also experiments with aerodynamic schemes of buildings affect the internal structure of the building. Therefore, the concept of runway unit in a building as a universal modular system was considered. It will allow to fully provide the functions of the ‘airport on the roof’ for any aerodynamic configuration. Further research is needed to study the stages of development of a new type of air transport for urban planning, the economy, and the safety of using passenger drone above the city.
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