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Computer Simulation of Wind Flow in the Urban Residential Planning Stage

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Abstract

This study discusses the pre-project analysis of the wind environment, which needs to be considered before the design and construction stage based on directions, wind speeds, and their repeatability. Wind conditions are important in developing urban environment, for various reasons. For example, wind flows management may help to mitigate urban microclimate. Therefore, our objective has been to study, experimentally and numerically, how urban morphology (for example, the orientation and configuration of residential buildings) impacts wind conditions in urban environments. This article discusses the initial study of the wind environment estimated before the design stage, with the results presented. Computer modeling simulation has been carried out using Autodesk Flow Design software, which helped us to easily perform a wind environment analysis with more confidence in the validity of project decisions. Flow Design is a 3D virtual wind tunnel software for airflow modeling, including areas around buildings / group of buildings. Using this program, we have created a simulation project overview, in order to obtain airflow visualization results, in geometric modelling and graphics format.

Keywords: microclimate, wind environment, microclimate modelling, wind speed, turbulence.

INTRODUCTION

Comprehensive consideration of natural and climatic factors is one of the most important stages in the residential development planning. All these factors shape the individual composition (volumetric, spatial) of urban and architectural units. Evaluation of these factors is especially important in a sharply continental climate, dry and hot in summer and with frequent winds in winter.

In this regard, we have carried out an architectural and climatic analysis of the background values of the meteorological elements in areas under consideration, intended for new building development. Another important factor exerting the most profound and multifaceted impact on the sanitary and hygienic conditions of the urban environment is the assessment of urban climate system [1].

At the first stage of our study, we have performed an architectural and climatic analysis, which is an integral part of the design process at any stage [2].

The climate of Samarkand is subtropical, with pronounced seasonality. In July, the daily shade temperature may exceed 40^0C. Samarkand is located on the slopes of the Turkestan range. During the dust storm seasons, the amount of heat from direct and scattered solar radiation may increase from 15 to 50% [3]. Also, the thermal situation in urban environment is complicated by reflecting sunlight from the surfaces of buildings, structures and other landscape elements.

According to experts on climate-related risks in Uzbekistan, by the middle of the century, the effects of global warming of 1.0-1.5°C will include increasing the number of rainless days in the region by 15-18% [4].

In the natural and climatic environment of Samarkand, it is extremely important to assess the influence of the hot summer season, when the surrounding environment overheating causes thermal discomfort.

The dry hot climate of Samarkand creates difficult conditions for the thermal interaction between the human body and its environment. Therefore, it is necessary to understand how various urban planning factors (building structures, landscape elements, etc.) affect a human thermal comfort, in order to choose the best urban planning solution for particular climatic conditions. As a result of assessing the urban climate and microclimate, we have presented diagrams of changes in individual meteorological factors, in particular, affected by the surface conditions (topography).

Thus, we have provided a generalized description of the factors included in the climate passport of the city, since such factors are related to urban planning requirements.

Nowadays, in the field of design, construction or development of urban areas in Uzbekistan, we can observe such a phenomenon as assimilation, or imitating of some construction patterns. This factor interferes with the semantic and ideological unity of historical cities in today's urban planning policy, since it does not take into account the natural and climatic conditions of Uzbekistan, or even completely ignores them. An example of the negative impact of such imitating is Samarkand, a city with an ancient and rich history.

Therefore, given the multifactorial nature that negatively affect the microclimate of residential area in design and development stage, we consider it necessary to study the spatial changes in the characteristics of the urban wind environment.

In summer, the wind environment of Samarkand is characterized by a predominance of easterly or south-easterly winds, followed by valley winds with a west component, i.e. south-westerly winds, with an average speed of 2.0 m/s.

Over the past 8-10 years, in different areas of Samarkand, residential 6-16 storey buildings, long and diverse in their architectural and planning configurations, have been erected.

In its turn, an increase in building density leads to an increase in surrounding environment temperature. In order to mitigate the heat load of a developing city, we have offered some landscaping ideas, including planting, watering, as well as specific construction methods, providing the necessary ventilation and shading of the residential area.

RESULTS

In order to evaluate and comparatively analyze the microclimatic conditions of the residential area development, the wind environment of the Motrid settlement has been modelled, taking into account local temperature conditions.

Airflow modelling, including different modes of operation, has been carried out in the Autodesk Flow Design software package - a family of programs for calculations and engineering analysis.

The simulation results have been displayed in the form of graphs and charts, that have been ordered by technical parameters. Space-planning decisions of residential development should be selected in accordance with the simulated wind environment of the Motrid settlement.

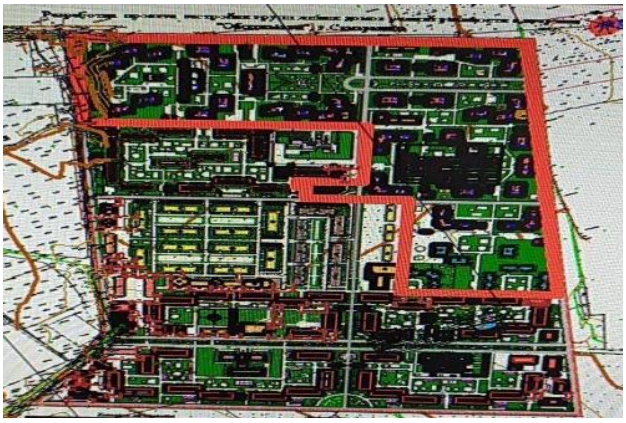

Fig. 1. Development plan in the investigated residential area.

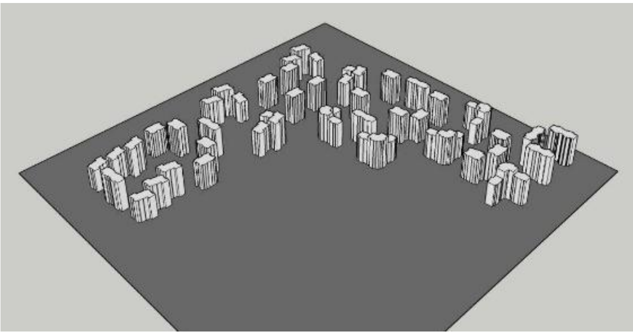

Fig. 2. Spatial model of a residential complex.

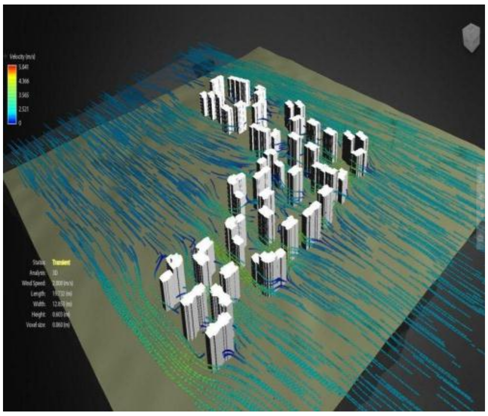

Fig. 3. Movement of easterly airflows at a speed V=2.0 m/s

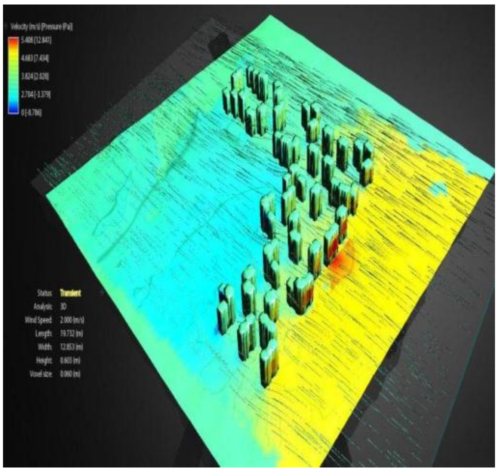

Fig. 4. Diagram of high and low turbulence zones.

In order to evaluate the wind environment of a given residential area, taking into account the recommended space-planning decision for a group of buildings, it is necessary to conduct laboratory studies of the airflow localized around residential buildings. The experiment has been carried out using Autodesk computer software that simulated the wind flow around a 3D model of residential buildings. Flow Design is a 3D virtual wind tunnel software for airflow modelling, including that localized around buildings or a group of buildings.

This study is similar to wind tunnel experimental research methods. In the process of modelling using software, we took into account all the parameters of residential development and the characteristics of the wind flow in a particular direction, as well as seasonality and a time period.

Below is an overview of the airflow in the near vicinity of 16 storey buildings of the residential complex under construction, located in Motrid settlement (Samarkand). Figures 1 and 2 show the plan and spatial model of the residential complex. The surface topografy in the near vicinity of the residential area has insignificant elevation difference. Flow simulation has been performed at 1:1 scale. The maximum height of the building in the complex (Fig. 3) is h_b, max ≈ 47 m. For the experiment, we have selected the most repeated wind speeds, according to KMK (Construction Norms & Regulations) 2.01.01-94

'Climatic And Physical-Geological data For Designing' for the summer and winter seasons, respectively: summer - easterly wind (V=2.0 m/s), where, according to the Beaufort scale (table for land), the wind strength ranged from 0 to 3 points [5, 10]. Fig. 3 shows the distribution of airflow movement and speed indices with an easterly wind V=2.0 m/s.

From the results obtained, one may observe stagnant air masses, which are mainly localized between the courtyard spaces or undeveloped areas. For this reason, the recommended layout of these buildings requires additional changes, in order to create maximum stimulation of micro-scale thermal convection, which will contribute to the vertical and horizontal movement of airflow near buildings and other structures. [6, 7].

Fig. 4 shows a diagram of increased and decreased turbulence zones. These are zones of formation of the airflow whirls, the number of which is insignificant in the areas under consideration, according to diagram. Fig. 4 shows the pressure fields on residential buildings from the wind flows. The pressure on the building sections does not exceed 12.8 Pa, which is also an insignificant value. In this case, the pressure fields are important for determining places on the building areas, where the wind flow resistance reaches its maximum values.

CONCLUSIONS

As a result, the simulation and computing technology used to model the airflow in an urban residential area with 16 storey buildings, has demonstrated the following final conclusions:

- the feasibility of construction of column-supported buildings [8];
- assessment of aeration comfort of the residential area;
- effective planning of the urban environment;
- we analyzed the turbulent airflow in the near vicinity of the urban residential area in the range of free flow velocities corresponding to normal atmospheric conditions.

It is worth noting that near the earth's surface, the wind speed decreases significantly. The change in the air-wind environment throughout the territory of residential areas depends on the specific character of urban development. The airflow system in the residential areas is quite complicated, and, in each case, the aeration mode is individual, taking into account the wind direction.

When designing a residential area, it is necessary to take proper measures to increase the speed of free wind flow in residential buildings. It is also important to avoid excessive insolation, reduce thermal effects on vertical and horizontal surfaces, create pools, artificial water reservoirs, and green areas. Along with the creation of green spaces and water reservoirs, it is necessary to increase the building albedo, by using light-colored materials on external vertical surfaces. It is also advisable to make the development northeastern- or eastern-oriented, that is, the direction from where the mountain-valley breeze blows. All of the above is especially true in hot climates. With that, it is necessary to make a general characteristic of the climate, taking into account not only its individual factors, but also the frequency and mutual influence of meteorological patterns.

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