DIGITAL MODELING IN THE FIELD OF CULTURAL HERITAGE PRESERVATION

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Abstract

The aim of this study is to identify new approaches to ensuring favorable conditions for people in the urban environment around the Registan Square during the high summer temperatures. This study examines a computer model that serves as a source of physical parameters and data necessary for creating a detailed simulation of the external microclimate of the Registan Square historical monument in Samarkand, encompassing both architectural elements and hypothetical adjacent green spaces in a hot climate.

The microclimate around historical monuments requires a scientific and accurate assessment of the surrounding environment. The subject of this detailed analysis was the temperature and aeration conditions near the monument. The use of CFD modeling at the pre-project analysis stage significantly optimizes the decision-making process in microlandscape design. Simulation results in Ansys Fluent indicate a decrease in air temperature and a change in wind speed in the green zone, which contributes to a more comfortable microclimate around the monument. The generated quantitative microlandscape layout scheme is suitable for determining the impact of wind characteristics and managing temperature conditions through a complex of green spaces that ensure a uniform and balanced flow of thermal energy into the surrounding area.

Keywords

Registan Square, modeling, historical Samarkand, microclimate, Ansys Fluent, microlandscape, green spaces

Introduction

From an environmental perspective, the use of microlandscapes to improve the microclimate in areas with historical buildings is highly relevant. Plants can mitigate the impact of abnormally high temperatures, contribute to a healthier atmosphere, and provide more pleasant living conditions. However, the selection of planting species and schemes requires scientific justification, taking into account many variables.

Samarkand, with its unique climatic conditions and active construction, is a suitable site for this research. In the local hot climate, the importance of green spaces for reducing temperatures and improving aeration increases exponentially. One of the pressing issues in modern design in areas of historical monuments is the creation of a microlandscape with a favorable microclimate, providing comfortable conditions for the effective development of domestic and international tourism.

Since temperature conditions dictate approaches to the ecological development of monuments, it becomes necessary to study air movement within the historical sites themselves as isolated entities. For open-air historical monuments, it is critical to ensure an appropriate temperature and humidity balance. Humidity levels directly correlate with the volume of planted vegetation and the frequency of watering. Landscaping along the inner perimeter of Registan Square is considered one possible way to integrate greenery.[1]

Over the past twenty years, numerical calculations of aeration systems have established themselves as a key element of urban design. Analysis of such problems is presented in the works of both domestic [2] and foreign (particularly Japanese) researchers, covered in more detail in specialized reference books [3], as well as in articles [4–7] and other publications. Mathematical modeling of air masses flowing around buildings and green spaces provides a detailed understanding of air velocity distribution, pressure, and turbulence. This opens up opportunities for assessing and managing the microclimate near historic buildings and vegetation, providing data on a scale unattainable through physical testing.

The synthesis of architectural and urban planning experience with computational fluid dynamics (CFD) methods is key to creating comfortable urban spaces. Conducting virtual tests provides detailed information on air flow trajectories and enables the simulation of processes at a wide range of scales. Consequently, the determination of aeration parameters for a given site, taking into account climatic conditions, can be quickly performed in a digital modeling environment [8] as part of ventilation studies [9].

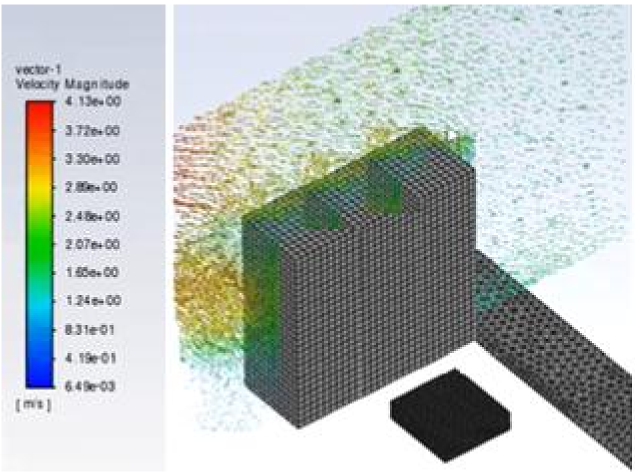

Fig. 1. Geometric spatial model of Registan Square with microlandscape and airflow velocity indicators

Materials and Methods

The microclimate modeling of Registan Square with a perimeter green area was performed using the Ansys Fluent software module (Fig. 1). A green area of Registan Square measuring 100 square meters was considered for the first stage of the study. This terrain area is characterized by a 2% slope, varying from 0 to 1°, which is typical of gently sloping plains.[10] In this case, the standard Realizable k-ε model of turbulent gas flow was used, based on the Reynolds solution of the Navier-Stokes equation. [11] The Reynolds value for external flows around an obstacle is assumed to be 10,000 units. The green area was defined as an isotropic porous region. [11, 12]

The geometric spatial model consists of four objects (Fig. 1):
a) the historic Registan building (solid region);
b) green space (porous region);
c) ground (flat region);
d) airflow (gaseous region).

The mesh was created in Ansys Meshing, a universal mesh generator integrated into the Ansys Workbench computing environment. The mesh model is non-uniform in cell shape and placement, with condensation areas around the buildings.

The green space mesh generation method is MultiZone with the All Quad mesh type. The airflow mesh was generated using the Proximity option, which provides a fine mesh size with a maximum skew of 0.49, a good result (Fig. 2).

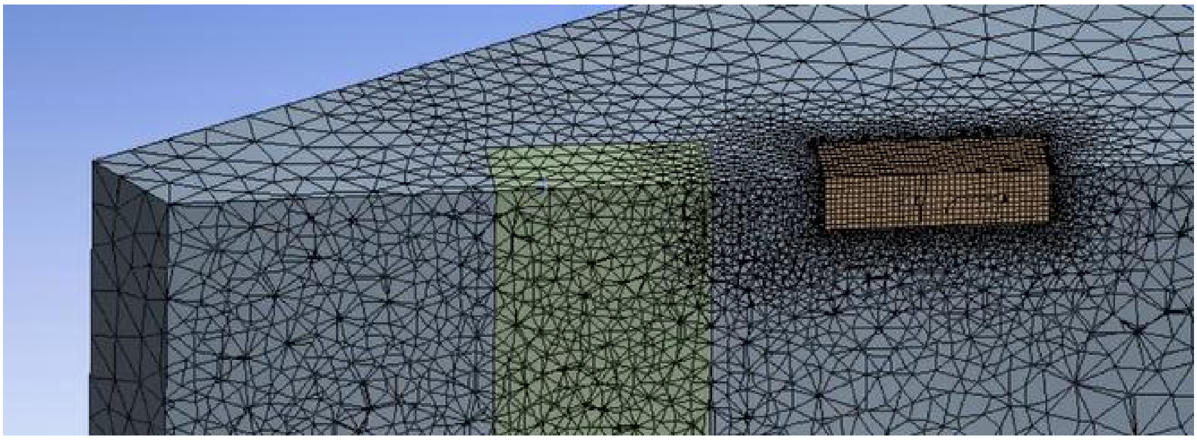

Fig. 2. Geometric mesh model in section: building, green area, airflow

Mesh – geometry of the green area for Fig. 2.

Table 1

Max размер элементов (м)	*Min размер элементов (м)*	*Min длина кромки (м)*	*Min размер кривизны (м)*	*Нормальный угол кривизны*
1,2175	*1,0117*	*0,5*	*1,e-003*	*18*

Fig. 3. Shows a diagram of the orthogonal quality of the completed mesh corresponding to the number of calculation elements of the selected models, where the predominant type of elements is a rectangular and tetrahedral mesh.

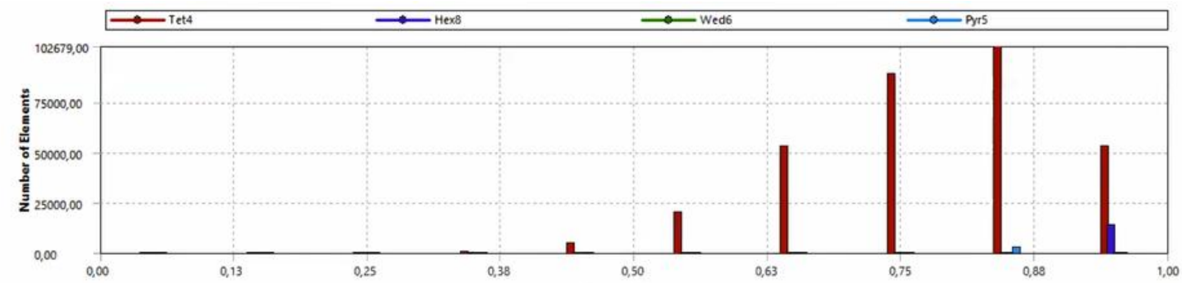

Fig. 3. Orthogonal quality diagram of a mesh network

The input parameters are pressure and velocity vector, and the output parameter is temperature. We used a viscous ideal gas model for the material, whose parameters correspond to those of the standard atmosphere at sea level: P = 101325 Pa, ρ = 1.225 kg/m3, T = 288.15 K.[11] The results are presented as comparative temperatures and wind speeds in the green area in front of the Registan building.

The airflow spreads over the concrete surface and heats it from +44°C to +67°C over the course of a day. Using the discrete ordinate radiation model in the porous body model eliminates the ability to specify nonequilibrium heat transfer, leading to an increase in temperature in the green area to +37°C.

Results and Discussion

ANSYS-Fluent demonstrates high accuracy and consistency in calculating microclimate characteristics. However, difficulties arose at the modeling stages, including constructing the computational mesh, defining boundary conditions, describing cell conditions, and defining material properties for objects lacking a standard library description. Furthermore, although the program's capabilities for calculating radiative heat transfer are quite robust, modeling trees represented as porous structures proved challenging (Fig. 2). However, for validation (Fig. 4) and testing the proposed computational scheme in simulated scenarios, this problem was overcome through the use of user-programmable functions (UDFs) and tables describing the dynamics of parameter changes over time.

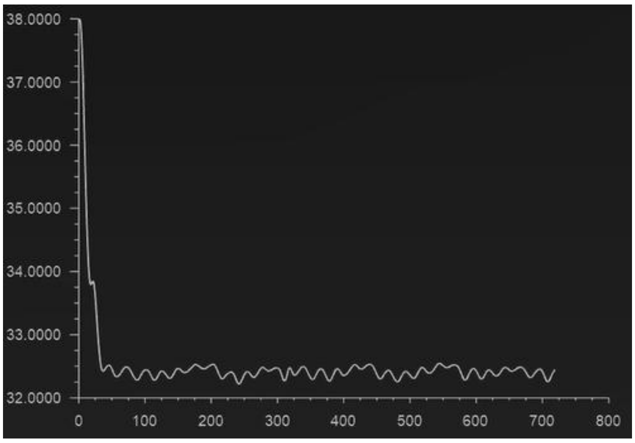

Fig. 4. Iteration diagram

Along the reinforced concrete pavement, with a microlandscape area present, a recirculation zone appears on the surface, where the airflow stagnates, reducing its velocity to zero. Outside, around the greenery, the velocity increases to 1.4 m/s (Fig. 1). The model describing the absorption of thermal energy by the greenery remains open. Since the planting area is 100 m2, the water consumption per m2 is 20 liters per day. The heat of evaporation of water is 2300 kJ/kg at atmospheric pressure. If we assume that all the water entering the trees from the soil evaporates, this will require

$$Q = F \times q \times L, [11]$$

where F is the planting area, q is the water consumption, and L is the specific heat of evaporation of water. As a result, we obtain Q = 4,600,000 W of thermal energy. The specific heat flux is 4,600,000 / 6.800 = 676.5 W/m³. With a heat flux of 676.5 W/m³ in the green area, we obtain the most effective temperature field of 28°C – 32.5°C.

Conclusion

Based on the data obtained during the computer modeling, we can conclude: if the proposed microlandscape is placed along the perimeter according to its design configuration, assuming a prevailing easterly wind speed of 2-3 m/s and irrigation of the vegetation, which will provide a heat load of 676.5 W/m³, then a temperature reduction of 5°C in shaded areas within the studied Registan area is possible.

The use of this numerical method made it possible to determine how exactly the green elements of the microlandscape contribute to improving conditions in the historic Registan Square. This is achieved through the ability of these areas to accumulate and absorb heat, thereby mitigating the "heat island" phenomenon by stabilizing the temperature regime of various surfaces in hot urban climates.

References

1.Sustainable Urbanization and Parking Planning in Samarkand. Elicit. https://elicit.com/notebook/b1f84061-e2f5-4a60-b5c4-0951f6772b31#17e064c98f41052f1a1e0cc96cea6217 Accessed July 9, 2024
2. A.V. Doroshenko, Methodology for numerical modeling of wind speeds and pedestrian comfort in residential areas. Cand. Engineering Sci. Diss. https://newdisser.ru/product_info.php?products_id=1086077. Accessed July 9, 2024
3. A. Mochida, Y. Tabata, T. Iwata, H. Yoshino, Examining tree canopy models for CFD prediction of wind environment at pedestrian level. J. Wind Eng. Ind. Aerodyn. **96**, 10 (2008) 1667-1677. https://doi.org/10.1016/j.jweia.2008.02.055
4. L. Ji, C. Shu, A. Gaur, L. Wang, and M. Lacasse, A state-of-the-art review of studies on urban green infrastructure for thermal resilient communities. Build. Environ. **257**, 111524 (2024) https://doi.org/10.1016/j.buildenv.2024.111524
5. R. Ooka, H. Chen, S. Kato, Study on optimum arrangement of trees for design of pleasant outdoor environment using multi-objective genetic algorithm and coupled simulation of convection, radiation and conduction. J. Wind Eng. Ind. Aerodyn. **96**, 10 (2008) 1733-1748 https://doi.org/10.1016/j.jweia.2008.02.039
6. K. Uehara, S. Wakamatsu, R. Ooka, Studies on critical Reynolds number indices for wind-tunnel experiments on flow within urban areas. Bound.-Layer Meteorol. **107**, 2(2003) 353-370 https://doi.org/10.1023/A:1022162807729
7. T. Okaze, K. Kikumoto, H. Ono, M. Imano, N. Ikegaya, T. Hasama, K., Nakao, Y.Tominaga, Large-eddy simulation of flow around an isolated building: A step-by-step analysis of influencing factors on turbulent statistics. Build. Environ. **202**, 108021 (2021).https://doi.org/10.1016/j.buildenv.2021.108021
8. ‘Effect of Water Regime and Soil Maintenance Mode on Vegetative Growth and Peach Tree Production. Indonesian Journal of Science and Technology **9**, 1 (2024). https://ejournal.upi.edu/index.php/ijost/article/view/64032
9. A. Castagnoli, S. Falcioni, E. Touloupakis, F. Pasciucco, E. Pasciucco, A. Michelotti, R.Iannelli, I. Pecorini, Influence of Aeration Rate on Uncoupled Fed Mixed Microbial Cultures for Polyhydroxybutyrate Production. Sustainability **16**, 7 (2024). https://doi.org/10.3390/su16072961
10. Mukhamedovna S. N. Computer simulation of wind flow in the urban residential planning stage //International Journal of Engineering Research and Technology. – 2021. – T. 13. – №. 12. – C. 4846-4848.
11. Salieva N., Xudoyberdiev A., Karimov F. Ecological Comfort of Green Spaces for Urban Parking //E3S Web of Conferences. – EDP Sciences, 2024. – T. 574. – C. 06003.
12. Салиева Ноиля Мухамедовна. (2023). ПОДГОТОВИТЕЛЬНЫЙ ЭТАП МОДЕЛИ ЖИЛОЙ ЗАСТРОЙКИ С ИСПОЛЬЗОВАНИЕМ ЧИСЛЕННЫХ МЕТОДОВ CFD В ПРОГРАММНОМ КОМПЛЕКСЕ ANSYS CFX.