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Features of assessment of bioclimatic comfort for modern residential buildings in hot-dry climates

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Abstract. The summer period is decisive for the comfort of residential construction in a hot dry climate. Modern development of residential areas in the countries of West Asian and Central Asian cities has medium and multi-storey buildings, which do not always take into account regional features and climate. Modern development of residential areas in the countries of West Asian and Central Asian cities has medium and multi-storey buildings, which do not always take into account regional features and climate. Typical climatic factors are: intensive solar radiation throughout the year; high summer temperature and low outdoor air humidity; without precipitation for five months; winds conducive to air exchange, and adverse winds from deserts, significant seasonal and diurnal temperature changes. The study of the experience of the formation of traditional folk architecture in the countries of Western and Central Asia made it possible to establish methods for design solutions that meet the requirements of an architectural and planning organization, taking into account the physical and technical factors of the urban environment. Traditional houses did not have window openings along two or three facades, as the windows faced the yard. The houses were blocked into groups, of which the residential block was formed in accordance with the type of minimal-, medium storey buildings and one or two level of roof construction. Residential groups were separated by narrow dead-end streets, which were constantly in shadow due to the overhang of the upper floors of the houses. Modern residential buildings significantly differ from the buildings of traditional quarters, used construction equipment and engineering infrastructure, which are elements of the "Smart City" concept. In this regard, it is necessary to assess the bioclimatic comfort of modern housing construction for the formation of a new quality of the urban environment and the combination of open and closed spaces.

1. Introduction

The growth of the mass demand of the population of West Asian countries in the modern convenient and economical urban housing began in the late 60s of the 20th century. The same process took place in Central Asia about 15 years earlier. The process of urbanization has been developing intensively in the Asian region for more than half a century. Expanding of the development of territories, a sharp increase in the volume of construction, an increase in the level of improvement of development are associated with urbanization. At the same time, housing construction is both a component of

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urbanization, and the basis for its future development. Urban development in Asia is also associated with the transformation of the society and the patriarchal way of life of the population, the reduction of traditional handicraft production, the change in the demographic structure; the formation of a new generation of a modern working population, whose life activity is influenced by modern world progress. This determines the new forms of housing, the needs for its spatial organization in the urban structure and the corresponding requirements for comfort.

The modern construction of multi-storey houses in the countries of West Asia does not have time to solve the problem of the housing crisis because of the rapid growth of demography and local military operations. This worsens the sanitary and hygienic conditions, increases the chaos and the pace of construction, as a result of which the quality of the building environment is reduced and bioclimatic comfort is not taken into account, and protection against overheating of buildings and territories is not performed. The need for housing is exacerbated by the accumulation of flows of refugees and rural populations in cities, as well as the destruction of housing due to hostilities in West Asia. This process is most active in the countries of the Persian Gulf, where the regulatory framework for urban planning for housing is absent for the entire time of modern existence of states. In this regard, the specific nature of climatic conditions is not reflected in the density of modern buildings, and the peculiarities of the way of life and the religious order of the local population are not taken into account in the design solutions of construction from foreign construction enterprises and investors. Decent housing is attracted to the modern scientific basis with the use of modern medium-storey and multi-storey buildings to eliminate the severity of the housing problem and provide the most numerous low-income urban population with comfortable.

2. Historical methods of development in a hot dry climate

The historical urban planning structure of populated areas of West Asia and Central Asia is entirely determined by the natural and climatic environment of the regional zones, as well as by the socium of countries. Composition-planning solutions of town-planning formations are represented by four main types:

Type 1- high-density town-planning types of structures, consisting of small, medium and multi-storey blocked buildings, adjacent to each other ends and densely located on the territory with narrow breaks-lanes between blocks;

Type 2- detached type of house (sometimes tower type), formed, usually on the terrain on individual sites or terraces.

Type 3- closed type of houses in residential neighborhoods with a protected inner courtyard, surrounded by relatively low buildings from 2 to 8 floors. A closed type of houses is found in the plains of large cities of Asia.

Type 4 - an allotment type of a dwelling house - a house with a plot of land intended for a garden with its own microclimate, protecting the building and people in the area from overheating.

The nature of the development of settlements on the whole tends to be compact. It is interesting that the modern chaotic development of the territories, carried out until recently without a town-planning regulation, demonstrates the same first two types of town-planning tradition: it is steadily formed as a compact structure with closely spaced buildings, narrow alleyways, and in some cases with a closed enclosed courtyard space, as in type 3.

The orientation of the streets is connected both with the functional organization of the settlement, and with the natural and climatic environment. The streets are often oriented in the directions (north-south and east-west) with curvatures, which are due, on the one hand, to the features of the relief, on the other hand - the need to protect against the sultry desert winds that carry dust and sand. The formation of narrow corridor streets has another purpose. They are corridors of ventilation and stimulate (by the difference of temperatures in their spaces) the movement of air masses in the courtyards and high-density atriums. The external composition of town-planning structures and the architecture of the building is distinguished by the high originality of the forms and the decorative and artistic decoration of the facades. Islam brought along strictly formulated life canons, realized in stable

traditions. This manifested in architecture and town planning, which accumulates all aspects of spiritual and material life, culture, philosophy and economic aspects of local population development.
Chaotic building type 1, type 2 and less often type 3 at the present stage, occurs in areas adjacent to roads and covers significant areas. At the same time there is no regulation of the elementary improvement, infrastructure and other attributes of modern urban planning. The chaotic character of the layout makes the building a little attractive in terms of progress, while the construction does not bear as incorrigible negatives as foreign industrial construction of housing on foreign projects, which can inflict irreparable damage on the historical appearance and microclimate of cities.

3. Analysis of results of studies of the aeration mode and principles of town-planning design of residential development

The formation of the principles of urban planning for mass urban residential development in a hot dry climate requires consideration of the aeration regime and the subsequent assessment of bioclimatic comfort. In order to achieve a better quality of the urban environment, it is advisable to use the principles of town planning design of the building taking into account the aeration that should be used in modern construction:

- The strict orientation of the planning structure of the building streets in the direction of the prevailing winds promotes airing in the summer period;
- A high-density, compact planning structure protects against unfavorable winds carrying dust and sand. The structure consists of residential groups-quarters with a closed perimentral building around the inner courtyard.
- For the purpose of effective aeration of the block, mid-rise and multi-storey buildings (traditionally 5-8 floors) should be formed, with accommodation in the upper floors in the areas of maximum air movement;
- The perimeter quarter has narrow corridor streets and arches (aeration streets) in the direction of favorable prevailing winds for airing the space of residential groups.
- The formation of external significant, open urban spaces (gardens, boulevards, squares) between quarters should be limited for the purpose of efficient aeration of residential groups,. The residential group is located around the inner yard space.
- Closed domestic courtyards should be "air-permeable", that is, between several buildings there must be arches or special aeration openings through the whole building to ensure that air is sucked into the yard.
- Narrow corridor streets (aeration streets) form streams of air masses for ventilation with the aim of reducing air temperature in the building, shading and protecting buildings from overheating. Aeration streets in the building can partially perform the same role as the element "Iwan" in the building. This requires a significant excess of the height of buildings in relation to the width of the street, expressed by the K coefficient which is an average of 9 to 12, (formula 1).

$$K = \frac{H}{B} = 9 \div 12 \quad (1)$$

  where, H is the average height of buildings, B is the width of the street.
- Formation of such proportions in the building, allows to achieve a temperature difference between insolated (heated by the sun) building parts and always shaded spaces of streets. The difference of even a few Celsius degrees is the motivating condition for the movement of air currents, i.e. aeration.
- Walkable roof-terraces (traditionally "Mafrazh") of the buildings of the quarter under new construction and reconstruction are a territorial and construction resource of development, form recreational areas in the quarter for internal use by tenants and are equipped with awnings and tents to protect buildings and people on the roof from overheating. Carneiro C,

Morello E, Voegtle T and Golay F wrote that like roof superstructures, that are crucial in the estimation of solar radiation [1].

- The outdoor street front of the quarter is a light-and-dark structure due to the plasticity and depth of the elements of the facades of buildings. This provides a temperature difference of air masses of several Celsius degrees, which serves as a factor in inducing aeration.
- Quarter buildings have a significant width of the hull between the outer street and the courtyard (more than 16 meters) to protect against overheating of the premises, the courtyard of the quarter and the location of the "Iwan" air wells in the floor plan.

The above design principles allow to form a building with an optimized aeration mode, which is confirmed when studying the movement of air masses in the quarter on models.

4. Results of studies of aerodynamic effects in perimeter residential construction

The perimeter residential quarter is a significant obstacle to air flows at the meso level. A closed perimeter with narrow aeration streets (the space between the ends of buildings) causes considerable turbulence in the flows at a high speed, which provides protection against strong winds carrying sand and dust from deserts. Ricci A, Kalkman I M, Blocken B, Repetto M P, Burlando M and Freda A demonstrated that at lower heights the wind profiles are strongly modified by the buildings, and the different degrees of precision of their geometry turn out to have a large effect on the flow, especially inside the narrow street and canal [2]. The proportions of the aeration streets allow a limited amount of air mass to pass only when their longitudinal axis coincides with the approximate direction of the wind. An angle of approximately 90 degrees between the horizontal airflow vector and the horizontal axis of the aeration street creates a detached flow at the corner of the building with jet-boundary breaks outside the perimeter and along the contour of the block. This ensures the local formation of several streams in the entrance space to the aeration street and high turbulence of these flows, which prevents the penetration of air masses deeper into the aeration street and the courtyard. The described aerodynamic effects allow creating a comfortable environment in the building with different wind directions.

The sides of the perimeter building are parallel and perpendicular to the vector of the wind before building in the winter and summer periods. Therefore, the amount of air flowing through the aeration streets between the buildings (Figure 1) of the building sides 1 and 2 is much larger than through the spaces between the buildings on the sides 3 and 4 of the building. Perimeter density (according to Ratter) and wind speed in the yard will be overestimated.

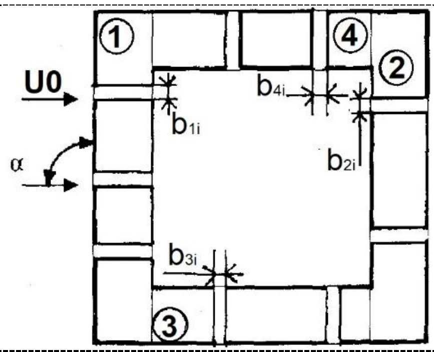

Figure 1. Scheme of perimeter building (U0 is the initial velocity at the approach of the wind flow to the building, α is the angle between the wind vector and the building in the intervals between the buildings, which directs the wind flow, and b are the gaps between the buildings

According to Ratter (formula 2):

$$\Sigma \text{bi} = \Sigma \text{b1i} + \Sigma \text{b2i} + \Sigma \text{b3i} + \Sigma \text{b4i} \quad (2)$$

where: Σ b1i is the sum of the gaps between buildings on side 1 of the perimeter building, m; Σ b2i - the same on the side 2, m; Σ b3i - the same on the side 3, m; Σ b4i - the same on the side 4, m.

In this case it is suggested to calculate the perimeter density in terms of Σ b1i + Σ b2i; adjustment (formula 3):

$$\Sigma\, bi = \Sigma\, b1i + \Sigma\, b2i \qquad (3)$$

where: Σ b1i is the sum of the gaps between buildings on side 1 of the perimeter building, m; Σ b2i - the same on the side 2, m.

Thus, the calculation of the sum of gaps between buildings is determined by the specific urban situation and the most repeated direction of the wind.

Separated flow also occurs on the roofs of buildings and forms a different aerodynamic effect. The air stream forms a jet-boundary layer after contact with the plane of the roof of the nearest building from the windward side of the block. Further, the size of the jet-boundary layer along the vertical increases as the flow moves over the yard space from zero along a linear regularity equal to 0.4-0.42 of the yard's size along the flow path. The collision of the air flow from the boundary layer to the second building, which is located on the windward side of the block, divides it into two approximately equal parts. The upper part of the stream continues to move over the roof of the second building. Poddaeva O, Churin P and Dunichkin I wrote that consideration of wind loads is an important part of the design [3]. The lower part of the stream changes the direction of motion for 90 degrees down the facade of the second building into the courtyard space and provides aeration of the quarter's living space.

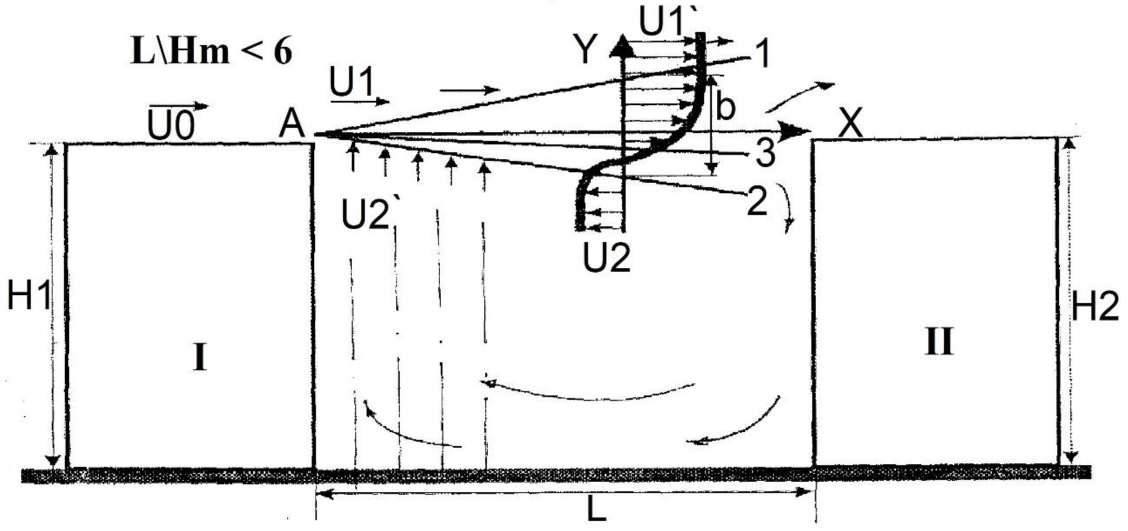

Figure 2. The flow separation scheme for two buildings of the perimeter quarter (line 1- upper, conditional boundary of the jet-boundary layer (JBL), line 2 - lower boundary of the JBL, line 3 - equivalent flow line (η 3), separating the flows: flowing in the second flowing building and flowing into the circulation zone between the buildings, b-vertical size of the JBL, U0 - initial flow velocity from the windward side of the building, H1- height of the building I, H2 -height of the building II, Hm - average height of the building, L - the yard size along the flow path, U1 - the velocity of the JBL flow, U2 - the flow velocity in the courtyard space)

5. Discussion of the bioclimatic comfort of development and the regulation of environmental parameters

When assessing the bioclimatic comfort of territories preferred for the resettlement of residents in West Asian and Central Asian cities (including migrants from rural areas and returning from abroad), especially those moving to a new age category, it is important to take into account the increasing requirements for comfort of living environment, both the surrounding (external) and the internal space of the residential quarter. Accounting of bioclimatic comfort in cities from the hot dry climate zone is a determining factor in the selection of territories for new housing construction and in the reconstruction of the existing urban development system.

The division into warm and cold seasons in assessing the bioclimatic comfort makes it possible to identify various ranges of comfortable wind speeds for summer and winter, and also to take into account molecular and radiative heat exchange, moisture fluxes between air, vegetation and active ground, taking into account phase transitions. It is the seasonal assessment of the bioclimatic comfort of development that uses the cycles of weather and climate conditions and generalizes the influence of vegetation, insolation, thermophysical characteristics of buildings and structures, heat and moisture exchange between air and elements of improvement on microclimatic parameters. The listed features of the assessment make it possible to identify places of discomfort in hot, dry climates in zones of high wind speeds, especially for the cold period, the place of overheating in areas of stagnant air for a warm period, and also to predict the locations of dust and sand from winds from the desert side.

Bioclimatic parameters of residential perimeter building in a hot dry climate have common regularities. The territory of the inner courtyard of the perimeter quarter will be organically ventilated by background winds in summer. Thermal convection will be induced under calm conditions around the insolated facades of the perimeter quarter, the wind speed in the adjacent area will be 0.75 m / s on the average. This speed is sufficient to ensure the bioclimatic comfort of the territory at temperatures from +16 to +30 Celsius degrees with the values of the main meteorological elements corresponding to the initial data of the hot dry climate. The parameters of bioclimatic comfort will almost everywhere correspond to the overheating of the environment and to the conditions of the spread of biological contaminants with a decrease in the airflow velocity below 0.75 m / s. Veremchuk L V, Yankova V I, Vitkina T I, Nazarenko A V and Golokhvast K S stated that the content of suspended particulate components of pollution remained more stable, due to the features of atmospheric circulation, rugged terrain and residential development [4]. The design solution affects not only the thermal comfort of a person, but also biological safety. Naboni E, Knudsen J, Von Seidlein L, Bruun R and Ikonomides K wrote that a prototype based on local construction techniques was built in order to understand the role of architecture in separating the disease vector [5]. The influence of design on climate is related to health, in particular the risk of infecting infectious diseases from biopathogenic microorganisms, which are usually often located near shaded building sites. Knudsen J and von Seidlein L demonstrated that the effect of design on the indoor climate and relate these factors to health [6]. In this case, especially strong overheating will be observed in the open spaces of the yard. Comfortable residence for a person will be where the supply of solar radiation is limited, for example, in the immediate vicinity (up to 5 meters) from the walls of buildings. Grosso M, Chiesa G and Nigra M demonstrated that nearer to building, a Venturi effect is evident, with consequent increases in the wind velocities [7]. With an increase in the height of the estimated space from 2 meters to 6 meters above the ground surface, the wind speed increases by approximately 1.5-2 times, which satisfies the conditions for airing and dispersing pollutants in the atmosphere relative to the building windows.
Discomfort from high wind speed will occur in different ways depending on the season. The wind speed will create discomfort in extreme weather conditions during the cold period (more than 4 m / s at a temperature of about 0 degrees Celsius) and in the warm period (more than 5 m / s at temperatures above 0 degrees Celsius). The movement of dust and sand from the desert side begins when the wind speed exceeds 6 m / s.

The parameters described above make it possible to estimate the comfort of the medium and the speed of the air masses, and to offer city-planning measures to compensate for discomfort for territories with environmental quality problems, with the help of gardening, small architectural forms and the addition of aeration streets. Grosso M, Chiesa G and Nigra M wrote that the predisposition of tree barriers with different height could represent an effective solution for curbing this potential discomfort situation [7].

The use of kinetic architecture for facades and small architectural forms will allow using shading to change the areas of insolated facades and territories, as well as sections of aeration streets. This will ensure the possibility of controlling the microclimate of the building. Kinetic architecture gives the greatest effect on climate regulation and bioclimatic comfort in an integrated approach that provides special equipment for shading all buildings of the perimeter quarter with the use of the Smart City concept for their automated management. Instruments of parametric modeling will allow to raise the design of the perimeter quarter in conditions of hot dry climate to a new level, however only if the boundary parameters of the building described above are observed. Naboni E wrote that – the most widely used parametric tool – allow the creation of mathematically originated geometries from environmental data such as solar geometry, wind direction and velocity, radiation intensity, illuminance levels, etc. However, a critical look at the application of parametric methods in the practice of design reveals that their use is still predominantly based on aesthetical, structural and fabrication criteria [8].This allows us to raise the question of the future evolution of the kinetic architecture of buildings in kinetic and parametric urban planning for neighborhoods and urban areas, which is significant not only for the conditions of hot dry climate.

6. Conclusions

The study allows to conduct urban planning for individual West Asian and Central Asian cities, determine the parameters of the environment for the formation of national standards for the construction of residential buildings, and also has the following main results:

- The social, economic, demographic and resource prerequisites for the development of the countries of West Asia and Central Asia are currently stimulating the processes of destruction under conditions of a hot dry climate.
- Historical composition and planning solutions for residential development have the main four types, of which Type 3 with a closed composition of houses and a protected courtyard has the most optimal aeration parameters and is the basis of an effective theoretic model of modern development in the form of a perimeter quarter.
- Aeration streets are used for aeration of the inner courtyard of the perimeter quarter, the width of which is not more than 1/9 of the average height of the building.
- The principles of urban development planning with regard to aeration allow to form an environment with optimal parameters for the conditions of hot dry climate
- Consideration of the detached flow of air masses made it possible to reveal aerodynamic effects in the building influencing the airing of the inner courtyard of the perimeter quarter.
- The obtained data on the proportions and dimensions of the building elements, wind speed, air temperature, orientation to the sides of the light, areas and location of shadows, zones of discomfort, and zones of stagnant air masses - are obligatory initial boundary data for parametric building simulation.
- The "Smart city" concept for the perimeter quarter in a hot dry climate automates the use of shading systems and other kinetic architecture equipment, allows you to manage climate parameters and consider automation of larger objects related to town planning.

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