DESIGN OF RESIDENTIAL COMPLEXES WITH ACCOUNT FOR CLIMATIC FACTORS

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Abstract

The article addresses an issue of designing and selling residential complexes without account for climatic characteristics of the territory. Main climatic factors affecting the urban environment, that shall be taken into account in design and construction, are considered. The article gives definitions to climate, climatic factors, local climatic factors, and windproof buildings. The state of the problem is studied, architectural and planning features regarding design of residential complexes exposed to the wind current in hot dry climate conditions are identified and analyzed, recommendations on design of the residential environment considering the above climatic factors are given.

Keywords

Residential complex, block, inner-block environment, climate, climatic factors, windproof buildings.

Introduction

Architecture has always been an integral part of human life. Houses have become one of the main means of people's protection against the unfavorable environment; with their help people transform the space around, trying to create the most convenient and safest living environment.

The Russian Federation has an extensive variety of natural and climatic conditions. Construction technologies and architectural and planning solutions acceptable for one region of the country can be completely unsuitable for life in another region. This trend can be analyzed by studying standard design solutions used in the territory of Russia and CIS countries during the Soviet period. In the Soviet times, large-scale residential construction was based on standard design solutions used for entire geographic regions. Standard projects were often developed without account for local climatic factors and the existing urban development directly affecting such local climatic factors, in particular, the wind direction and wind strength. The idea of regional typification of buildings was proposed back in the Soviet era, and despite the attempts of individual creative teams to start the development of such projects, it was not supported. One of the problems was the absence of a well-developed theoretical framework that would determine design methods for certain climatic conditions.

Nowadays, when performing design tasks, architects and representatives of related trades consider the area climate mainly with regard to the choice of a construction system and construction materials that should withstand wind and snow loads, precipitation, temperature fluctuations, etc. The climate should be considered not only in the selection of structures and construction materials, but also with regard to its influence on the urban development pattern, orientation and height of buildings. It also should be reflected in architectural and planning solutions as climatic factors directly affect the building operation. Based on the climatic factors of the territory, it is possible to create a unique architectural appearance, appropriate to the climatic zone and specific territory. Even our ancestors learned from their own experience and

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mistakes to adapt their houses to climate conditions, and select means of their protection against the unfavorable environment, which subsequently led to the formation of certain building archetypes and established the national identity of architecture in particular areas.

Climatic factors and their influence on the residential environment of blocks

The issue of climate impact on houses has interested many generations of architects. The concept of climate refers to the long-term weather pattern typical for a particular territory (Neklyukova, 2010). Just like the weather, the climate depends on the geographical latitude determining the amount of solar radiation coming to the earth's surface, altitude above the sea level, presence of water reservoirs, nature of the underlying surface, ground relief, nature of air masses and atmospheric fronts movement, i.e. on numerous climatic factors. Climatic factors (hereinafter referred to as CFs) are conditions that determine the climate of the territory. Disregarding climatic factors adversely affects the development of modern architecture, hinders the establishment of comfortable microclimate in premises, increases heat losses of buildings. CFs typical for the territory of one small city, settlement, or district are called local CFs and characterized by the air temperature (average annual, January and July temperatures), amount and type of precipitation, prevailing wind directions (Petrova, 2016), amount of solar radiation coming to the surface, water supply, dust/wind transfer, ground relief (in particular, angles of slopes and orientation to cardinal directions), development pattern, extent and pattern of green areas (Litskevich, 1984), seismic activity, etc.

One of the important microclimate factors undergoing significant changes under the influence of urban development and having a strong effect on the urban environment and residential buildings is wind. The irrational orientation of buildings, lack of consideration of the prevailing winds create areas of accumulating and increasing wind currents that adversely affect building constructions, create wind corridors in the urban space, and, therefore, adversely affect the living environment. Besides, a combination of wind with other CFs is also of great importance. Shortage or surplus of solar radiation, impact of strong wind and absence of wind currents have a significant adverse effect on the microclimate in premises and inner-block spaces. If low wind speed can be useful (for through ventilation of premises), especially for hot climatic zones, strong winds can cause significant damage to building structures, facings and internal courtyard spaces, and, therefore, adversely affect the life of people.

During the Soviet era, data were collected on the basis of already implemented projects. Territories were analyzed, data on the climate, on the effect of wind on urban development and on the microclimate environment of blocks were collected, wind behavior in the residential environment of blocks was investigated, methods of protection, as well as ways of regulating and reducing the wind current speed were proposed. The studies conducted were devoted to the conditions of the Far North, as well as the central part of the country, where low temperatures in combination with winds as well as snow/wind transfers were the main factors. Temperature fluctuations in the courtyard spaces, depending on the width of courtyards and passages, angle of sunlight incidence, changes in

Beaufort number	Wind description	Sea and land conditions	Wind speed, m/s
0	Calm	Smoke rises vertically	0.3
1	Light air	Direction shown by smoke drift but not by wind vanes	0.6–1.7
2	Light breeze	Wind felt on face; leaves rustle; wind vane moved by wind..........	1.8–3.3
3	Gentle breeze	Leaves in constant motion; light flags extended	3.4–5.2
4	Moderate breeze	Wind raises dust and loose paper. Small branches moved..........	5.3–7.4
5	Fresh breeze	Small trees in leaf begin to sway	7.5–9.8
6	Strong breeze	Large branches in motion; whistling heard in telegraph wires	9.9–12.4
7	High wind, near gale	Whole trees in motion..........	12.5–15.2
8	Gale	Twigs break off trees; generally impedes progress..........	15.3–18.2
9	Strong gale	Slight structural damage (chimney pots removed)	18.3–21.5
10	Storm	Trees uprooted; considerable structural damage..........	21.6–25.4
11	Violent storm	Very rarely experienced; accompanied by widespread damage	25.5–29.2
12	Hurricane force		More than 29.3

Figure 1. The Beaufort Scale

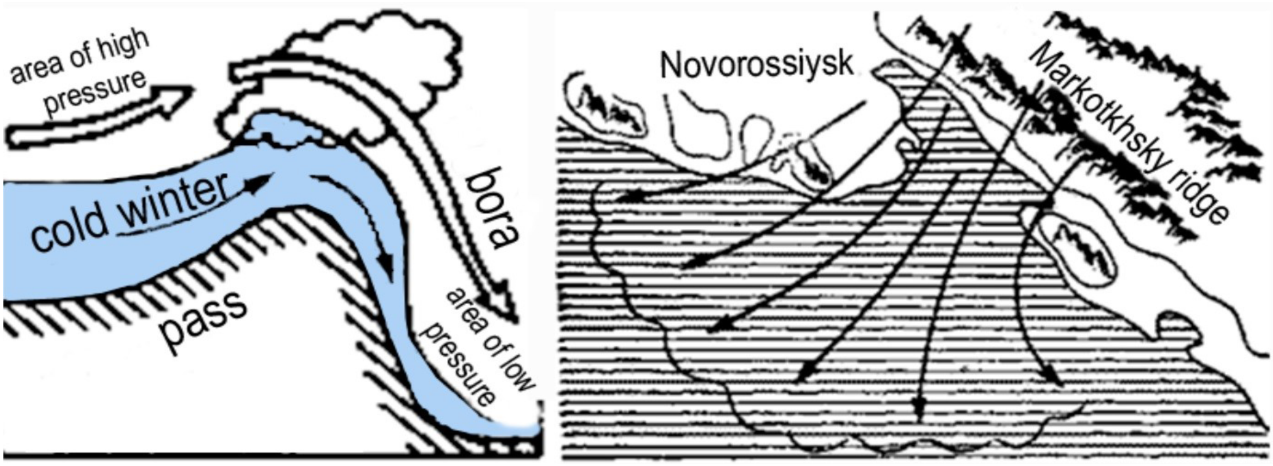

Figure 2. A diagram of bora occurrence

local factors under the influence of urban development, as well as their impact on health and well-being of settlement inhabitants were analyzed. As a result, the collection of such data took several decades.

Strong winds with a hot dry climate represent a rare combination of local CFs. As it was mentioned above, the adverse effect of wind on the residential environment in our country is often associated with negative temperatures (thermal effects) and blizzards. The most unfavorable combinations of temperatures and wind speeds are as follows: -30ºC and 1.5 m/s, -25ºC and 2 m/s, -15ºC and 3.5 m/s, as well as 5 m/s and higher at any temperature (Pivkin, 1971). Moreover, wind can have not only thermal, but also dynamic effect (Penwarden, 1975). Dynamic effects are perceived at a wind speed of more than 5 m/s. (Nikolopoulou, 2002). Wind speeds from 12.5 to 15.2 m/s are classified as "high wind" ("near gale") according to the Beaufort scale (Figure 1), when progress is impeded. Winds stronger than 15.3 m/s are classified as gale, strong gale, storm and violet storm, when chimneys fall, trees are uprooted; at the wind speed of 25 m/s widespread damage is observed. Wind speeds over 29.3 m/s are classified as a "hurricane force" (Aronin, 1958).

Here it is worth mentioning a unique natural phenomenon called "bora" or "north-eastern wind" which is a strong cold gusty wind blowing mainly during the cold season (approximately from November to March) down the mountain slopes and bringing a considerable temperature drop (a temperature drop of 15ºC degrees was recorded). It is observed in areas where a low mountain range borders on a warm sea (Figure 2). Violent bora winds can be felt in Italy (Trieste), Croatia (Rijeka, Zadar, Senj), and France. In the territory of the Russian Federation, this phenomenon is observed near the coasts of Lake Baikal, the city of Pevek, as well as in Novorossiysk (Tsemes bay; it also affects the Gelendzhik Bay), where the "north-eastern wind" became a landmark of the city (speed of the main wind current is about 45 m/s with gusts up to 70 m/s). Novorossiysk, Trieste, Rijeka, etc. have similar climatic factors: the presence of a warm sea, average minimum temperatures not lower than 2.7ºC, average summer temperatures equal to about 27.4/28.1ºC. Thus, upon design of residential blocks in the territories considered, repetitive hurricane winds (with their average duration in Novorossiysk of 50 days per year) in winter and a hot dry climate in summer shall be taken into account in urban planning and architectural solutions for residential complexes.

The main means of protecting the inner-block environment against strong winds are windproof screens which are usually represented by windproof buildings, as well as green windbreaks. A windproof building is a long windscreen building located on the border of a residential territory, protecting it against unfavorable winds. One of the most frequently used solutions is the arrangement of green areas (Figure 3). Such areas are considered efficient if they consist of 2–3 rows with a 40–50% clearance: in this case it is possible to reduce the wind speed by 50–80%.

In the course of field studies, as well as studies using the wind tunnel to test residential blocks, it was determined that windproof buildings located perpendicular to the direction of the prevailing wind current are subject to significant turbulence of the air current, gustiness of the flow; they also experience supercooling in winter and overheating in

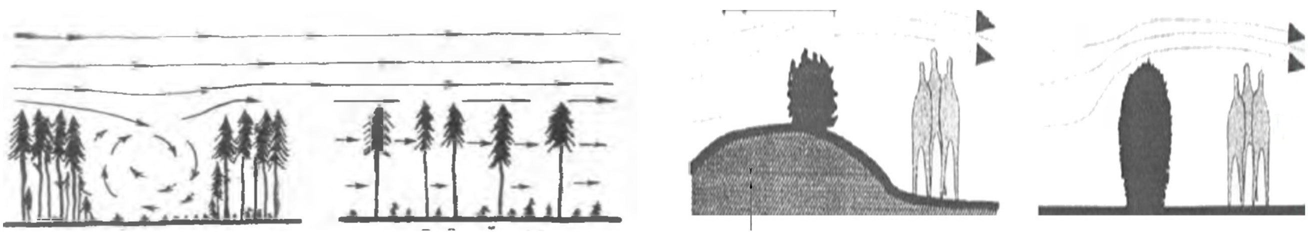

Figure 3. Wind movement on a cleared forest site and in a sparse forest

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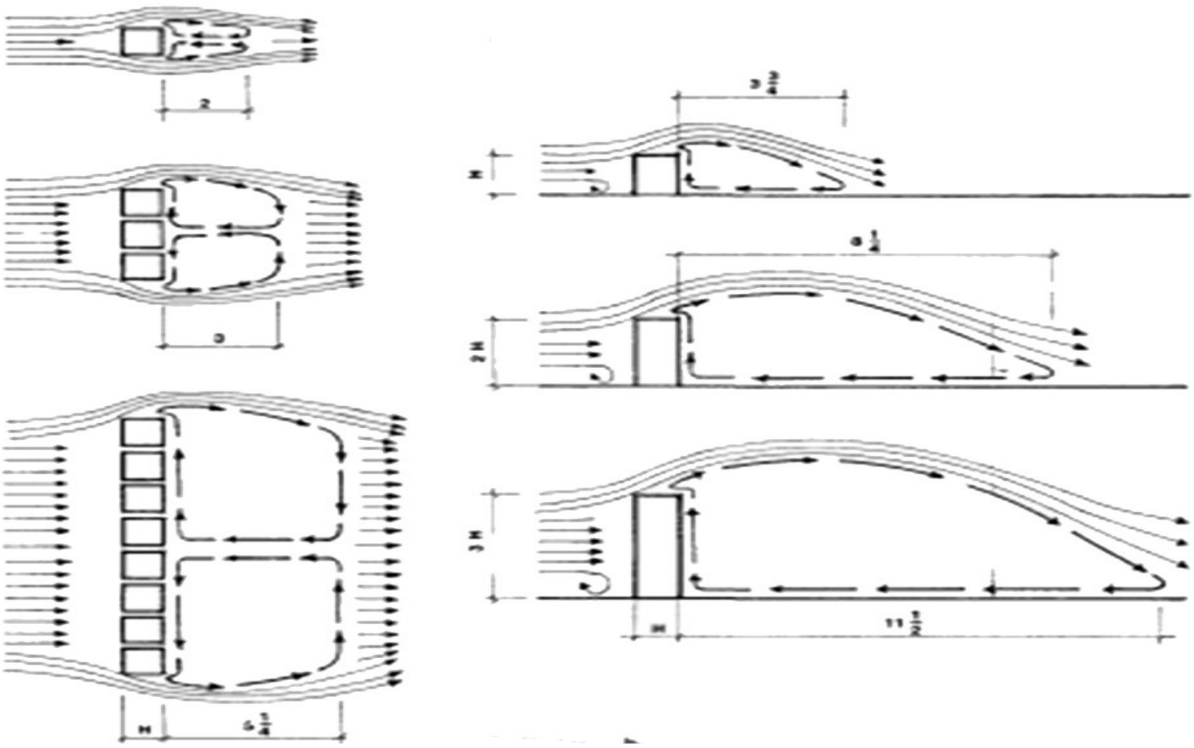

Figure 4. The wind shadow of buildings, depending on the length and height of the windproof building.

summer, if we speak about premises facing the windward side. It is possible to reduce the wind speed by about 40% (Pivkin, 1971). Heat losses of buildings due to wind cooling make up 20% of total heat losses (Litskevich, 1984). Such problems can be solved by bilateral orientation of apartments, ensuring the equalization of temperatures in premises facing the windward and downwind sides, as well as by such engineering solutions as triple glazing, air conditioning, arrangement of blinds, etc.

After a wind current passes a windproof building, at a distance equal to four heights of the building (4h), wind vortices and reverse currents form and descend to the inner-block environment (Figure 4). To eliminate this phenomenon, it is necessary to take windproof measures of the "second" order, i.e. to stipulate for rows of wind-blocking trees or a building at a distance of 2h/3h from the first building. The angle of building orientation relative to the prevailing winds as well as residential groups (usually perpendicular to the wind current or with a deflection of 20/30 degrees) plays a significant role. The wind shadow of a building also depends on the building shape and height: the narrower, the taller and the higher the building is, the larger the wind shadow it casts, therefore, it is better from the windproof point of view (Pivkin, 1971). We also should not forget about strong upward wind currents created near high-rise and excess height buildings as these currents adversely affect the residential environment of blocks (Litskevich, 1984).

Groups of buildings were analyzed by scientists and some aerodynamic effects describing the influence of the building location on the formation of air currents were identified. One of such phenomena is the "effect of a horizontally located building," where an air current colliding with a horizontally located building is thrown over the building, descending into the internal courtyard space at an angle of about 45ºC, thus forming wind vortices. "The effect of passages under high-rise buildings" resides in behavior of wind currents in through passages connecting

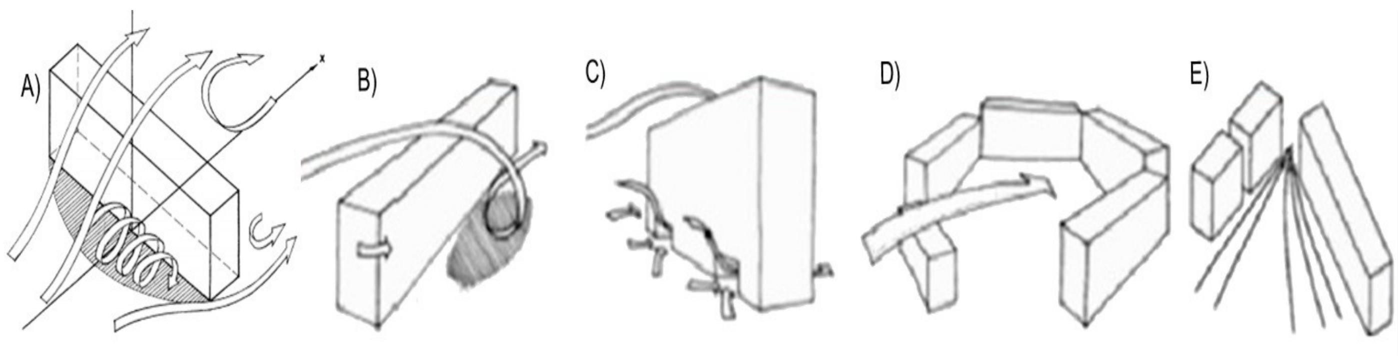

Figure 5. Aerodynamic wind effects: A) distribution of vortices on the windward side of the building, B) the effect of a horizontally located building, C) the effect of passages under high-rise buildings, D) the cell effect, E) the Venturi flue effect

the windward and downwind sides of buildings. On the opposite sides of a building, different levels of pressure form, wind moves from the high-pressure area to the low-pressure area, causing an increase in the wind speed in passages. Moreover, it has been revealed that as the number of floors increases, the pressure difference increases as well (the higher the building is, the less favorable passage it has). The "Venturi effect" or "flue effect" is quite common: it is generated by buildings forming an angle or a narrowing passage in the direction of the wind current (Jedid, 2016). The wind current grows stronger in the narrowing area of the passage (Figure 5). In a hot climate, this effect is used to enhance the existing wind current and pull it into the internal courtyard space.

In the course field microclimatic observations, it has been established that perimetral (closed) development is more preferable for winter conditions (adverse wind effect), and ribbon development is more preferable for summer conditions (Pivkin, 1971). Based on this, it can be concluded that the optimal solution for territories with strong winds and a hot dry climate will be a mixed block structure combining semi-closed development involving windproof buildings on the windward side and ribbon development on the downwind side of the block (Figures 6, 7).

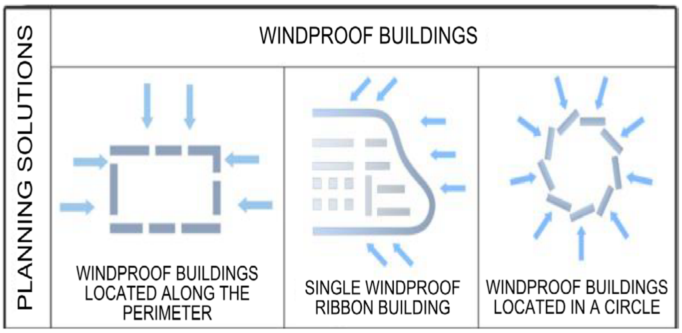

Figure 6. Urban-planning solutions for blocks of windproof buildings. An adverse wind effect

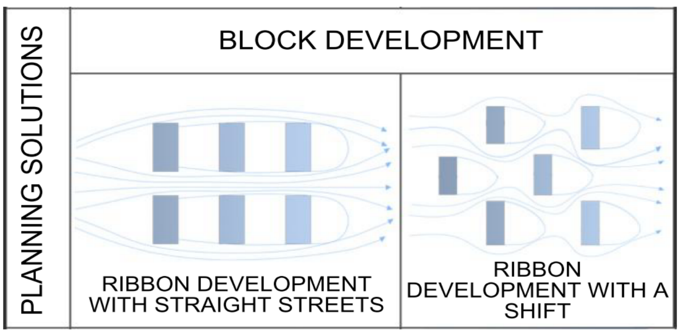

Figure 7. Urban-planning solutions for blocks in areas with favorable winds

Countries with a hot dry climate often consider wind protection in combination with protection against sands ("dust/wind transfer"). The following architectural and urban-planning solutions are typical for territories with a hot dry climate (significant overheating in summer at low humidity): closed nature of building operation, dense development, narrow corridors of streets create shaded passages (the ratio of the height of buildings to the width between them is more than 1). Canopies, protruding overhangs, brise-soleils (Bairamova, 2017), stationary or mobile sun protection structures (blinds, fins, etc.) are widespread. Artificial cooling of premises is used, natural ventilation is organized without lowering of the required level of moisture content; air permeability, heat protection are ensured. In order to provide natural ventilation, apartments are located on both sides of residential buildings. In a hot climate, a low wind speed is favorable, since such wind cools surfaces, therefore, premises and passages between courtyards are oriented in such a way as to catch a favorable wind current, and sometimes buildings are arranged above the ground on pylons, which provides additional shading and pulls wind into the courtyards.

Results and Discussion

It is necessary not only to adapt to the climate, especially to its physical effects on the living organism, but also benefit from climatic factors affecting a particular territory. Considering basic climatic factors of the territory, it is possible to create rational spaces needed for human activity, e.g. install wind generators in areas with constant favorable winds, as well as ensure through ventilation of premises, install solar batteries in southern regions of the country where clear, sunny weather prevails and there is a large amount of solar radiation.

Despite the development and growth of cities, the relationship between nature and man is indissoluble. At the present time, the emergence and development of new technologies, high pace of construction pose new challenges before architects, including an important problem of linking nature and climate with architecture.

Thus, the relevance of the topic is due, on the one hand, to the current urban-planning and architectural practice in Russian cities (not based on individual climatic conditions of specific regions) and, on the other hand, to the growing needs of society in the formation of an environmentally sustainable and comfortable environment that would meet the specific natural conditions.

Conclusions

The search for the optimal solution for the interconnection of climatic factors is carried out in a specific territory with account for the wind rose (directions of hurricane winds (bora winds) and favorable winds' movement), geographical location (angle of sunlight incidence). Significant adjustments can be made due to the inclusion of additional factors such as ground relief, seismic activity, etc.

Thus, during the analysis of climatic conditions, where the combination of unfavorable winds in winter and a hot dry climate in summer has a significant influence, we have obtained the requirements that, in fact, contradict each other:

1. windproof buildings and the following rows of buildings shall be located perpendicularly or with a

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deflection of 20/30 degrees from the main wind current (wind protection);

2. residential premises, courtyard spaces and pedestrian paths shall be oriented along the main wind current (protection against overheating).

However, we can distinguish several common features as well:

- premises' orientation to both sides of the building;
- provision of natural ventilation;
- a need for heat protection of buildings: in one case, against heat, and in another — against cooling by wind;
- a closed structure of courtyard spaces, protecting, in one case, against descending wind vortices and wind speed increase, and in another — against excessive insolation, hot wind and sand.

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