Accommodation of buildings on slopes taking into account bioclimatic comfort and safety

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Abstract. Currently, the question of the adaptation and reclamation of slope areas is important and relevant. Many of these lands are valuable in terms of town planning, have good conditions for the development of infrastructure and have a great potential for formation of scenic landscape for urban development. In the territories, converted industrial enterprises have already altered the natural temperature and humidity, hydrological regimes and aeration, which inevitably effect quality of living spaces. This quality is estimated by bioclimatic comfort and safety due the sum of factors of aeration and temperature and humidity conditions. That is why, development of these areas, valuable in terms of urban lands, is impossible to use without study and restoration of their bioclimatic comfort and safety. Researches have allowed to establish a qualitative and quantitative picture of the flow patterns of the air flow depending on the shape of the quarry in terms of the parameters of the quarry cross section and its orientation in relation to the incoming flow. It is important to establish how the exposure of a slope and its topography, as well as terraced arrangement of urban development, will have effect on the bioclimatic comfort and safety, change of the aeration mode.

1. Introduction

Most interesting are the slope areas according to the type of dredging-ground surface excavation, quarries and open pit mining. It should be noted that the load carrying capacity of the Foundation soil excavation best suited for the rapid development of urban development. Such areas gain importance in the conditions of deficiency of reserve territories for the development of cities [1].

In this regard, is of great research interest to study and conduct nodesign of experiment for the organization of the terraced city building on the slope areas according to the type of seizure. It is important to establish how the exposure of the slope and its elevation, and also the terraced arrangement of urban development will affect the bioclimatic comfort and the change of the aeration mode, which have strong influence on inhabitants of this area [2]. Naboni, E claims that outdoor climate studies indicate that the conditions expressed by the Physiological Equivalent Temperature (PET) – one of the most accepted models for outdoor comfort – are dependent on the radiation exposure and on wind velocity [3]. The aerodynamic characteristics of the active surface and building, landscape gardening, small architectural forms will contribute to a change of direction, speed and turbulence of the air flow along with terrain drops [4]. Classification of methods of building,
gardening and landscaping terms of bioclimatic comfort will allow you to identify patterns in their planning structure, height and composition, and thereby determine the optimal proportions for their recommendations in the design practice.

2. Method of determination of the Wind Regime of Technogenic Relief Forms

Studies of the flow around the wind flow technogenic relief forms allow you to retrieve the patterns, the quantitative characteristics of this process and based on them create recommendations for the improvement of the aeration mode on the recovered territories. Olenkov V.D. established that the methodology is based on the results of experimental studies using the method of physical modeling in an air tunnel [5].

In contrast to field observations, research in the wind tunnel allow you to vary the geometric parameters of the manmade terrain, direction, speed, and the initial turbulence of the air flow, so you should give preference to tests [6]. Experimental investigations using physical simulation in the wind tunnel based on the modern theory of aerodynamic similarity. Geometric similarity is ensured by careful preparation of the model in a certain scale. The kinematic similarity of the incoming air flow is ensured by installation of the nozzles in the wind tunnel a special grid, recreating a variable vertical profile of flow velocity [7]. The dynamic similarity of the simulated air flow field is provided by the similarity of the structure of turbulence, characterized by velocity turbulent energy dissipation and the equation of turbulent Reynolds numbers [8].

In the flow of air flow of quarry dredging a trapezoidal cross section at an angle of 90° to the longitudinal axis of the recess 3 is formed zone change air velocity: low velocity zone above the notch within its borders on the ground level and 2 zones with higher velocities in the territory adjacent to the leeward slope. Change the speed of the air flow over the contours of the quarry excavation is observed at a distance equal to two or three depths of cut and visible there in more steep slopes.

In the flow of air flow of the quarry of recesses of different widths observed at the level of the bottom change the speed of the air flow. With the increase of the width of the recesses transformation ratio of the air flow increases, which promotes natural ventilation quarry recess [9]. The conducted research also confirmed the dependence of the nature of the movement of the air flow around the quarry of the recess, the angle of inclination of the leeward side of the recess. When the value of the tilt angle less than 15° there is some movement of air parallel flow scheme, with higher values for recirculation. If you increase the width of the quarry excavation at the level of the bottom area of the ventilation recesses at the recycling scheme is reduced (when the inclination of the sides of more than 15°), which contributes to its improved ventilation in the flow diagram (Figure 1).

![Figure 1. Transformation of the air flow around the quarry of the recess a trapezoidal cross section at an angle of 90 degrees.](image-url)
Quarrying on the type of seizure interesting building and architectural reclamation also due to its relief. Terraced slopes obtained in the extraction process allow to obtain relief, which becomes an important component of a dynamic and dramatic composition development [10]. Experiment-specific pilot quarry with further aerodynamic testing will identify the most effective compositional techniques without losing the quality of the human environment. This will greatly facilitate the process of designing the urban environment not only in disturbed areas (slopes), but also in the construction of slopes and floodplains with complex topography. Based on the information we are able to organize the quality of the environment, taking into account the conditions for compliance and the improvement of quality of environment, to calculate the possible risks when building in these areas. A vivid example of disturbed land that require reclamation are coal mines in the Kuznetsk coal basin. For example, a quarry development city Mezhdurechensk and Bachatskiy coal mine. The recent rise is not only a question of restoration, but the question of further targeted use of such areas after the conduct of mine technical and biological stages of recultivation.

3. Results of architectural recultivation and the choice of buildings composition

At the moment, slope areas successfully designed and implemented the Park area. Prominent examples are the Park on mount Lycabetus in Athens on the site of a stone quarry, and Alexander Park in Ordzhonikidze, a beautiful Park, but Chaumont in France on the site of an abandoned quarry and the Park of culture and leisure in the city of Katowice in Poland on the part of the coal and stone quarries. Such parks are of great interest, because a fairly steep changes in topography creates a unique and picturesque view that is not only attractive factor for visitors, but also dynamic, ennobling element of urban structure. But in order to be able to examine slope areas as reserve areas for urban residential development requires additional research.

Currently available full typology of residential buildings, suitable for construction on the difficult terrain [11]. In our case it will be interesting to consider the types of residential buildings structural part which will be in addition to the other additional element reinforcing the slope to prevent landslides. This type is the "buried house", where the surface comes only a facade, the rest of the volume is located underground. This typological method allows to provide good insulation, environmentally friendly and cost efficient buildings. Due to the fact that part of the building is underground, we get an additional free land that the buildings in a limited area of the terraces is a definite plus.

The walls of the building in addition to the protecting functions can perform the function reinforcing the slope. The second considered type of building is "building on open piles". – type houses, standing on open supports. Such supports can also be used for reinforcing the slope with reinforcement. Also this type of interesting themes that can be used on slopes with dense and high vegetation, which is important for lands that have passed the stage of biological reclamation. At the same time, the necessary measures for insulation walling of the house that leads to a rise in construction. The following type of buildings suitable for development on slope areas by type of seizure is a "home console" with fixed one side and free the second. Also, as the "buried house" is suitable for designing s the shortage of built-up area. Allows you to obtain a spectacular panoramic view. This type of house can be built in areas of extreme terrain for the house which is located freely, you can also use a retaining wall for additional support and strengthening of the slope. Another type of the property of interest is the "house phantom"[12]. Type mimics natural terrain to blend into it. In addition to the use of structural building elements for strengthening the slope by using this type, we get the possibility of connection with the city-use it in the buffer and transition zones [13]. Finally, the most common type of house in the building on the relief is "terraced house" composed by ledges (figure 2). This type of house is easy enough to fit into the existing topography. Structural elements can also be used as a reinforcement of the slope. Apart from anything it allows you to organize fairly dense housing and lack of space at home to offset the expense of the terraces. The houses of type "terraced house" and "embedded" the house is possible and rational use of atriums.
Speaking of bioclimatic comfort is important to mention not only about the methods of adjustment of external factors, but also on the control of comfort within the building. Since the construction in conditions of slope areas often means dealing with harsh climatic conditions, residential development should be as energy efficient as possible [14]. One of these internal methods is the organization of the Atria. The use of the atrium allows maximum use of the potential of solar energy and in some cases can reduce costs of heating, and also create inside the building natural lighting and climate conditions (figure 3). Besides the fact that the atrium of the building provide efficient use of space, they add to the pedestrian space that can serve as a communications and places of concentration of different activities. The use of atriums in a residential building allows you to effectively use solar energy so that it becomes possible to control the indoor climate taking into account energy conservation. The comfort of the internal environment of an atrium building is formed due to the effect of the aerodynamic thrust and the greenhouse effect, whereby heat energy remains in the room and there is a positive effect in winter and negative for summer.

Grosso M., Chiesa G., Nigra M. wrote that the environmental aspects of the preliminary design process are related to the assessment of all factors affecting the impacts of the building-to-be-designed on the physical context at various scales: spatial, i.e., global, regional, local, and indoor/outdoor as
well as temporal [15]. Having considered the various types of houses suitable for building a relief it must be concluded that the choice of the typology of space-planning decisions depend on the layout relative to the slope. But the layout depends on the choice of compositional technique. Despite the fact that today, there is enough information on the existing complex terrain types of homes classification and analysis of composite methods of construction taking into account bioclimatic comfort, providing a high quality living space.

4. Discussion of composition of urban layout

The composition of urban development on slope areas of the type of seizure depends on many factors, such as the area under construction of terraces, slope, elevation, soil properties, selected the number of floors, types of building, road-transport system, temperature and humidity, speed of wind flow and the degree of greening. Dunichkin I.V. and Egorychev O.O. identify that urban climate is essential from the viewpoint of temperature, humidity, gas concentration, and air pollution. Any research into the urban climate includes the study of the residential housing density, efficient use of urban facilities, as well as the multi-component assessment of the wind energy potential. Also it is necessary to say that Oliveira S. and Andrade H. established that wind was found to be the most intensely perceived variable, usually negatively. Wind perception depends largely on the extreme values of wind speed and wind variability [16].

The most effective compositional scheme with the features of the terraced slope areas on the type of seizure is a functional flow diagram of the buildings by N. Milyutin. But for a city building violated terraced slopes you need to make some changes on the basis of the scheme is to develop several options for further design of the experiment. In this situation it is rational to replace the production area to the public. Based on the ability of selected types of houses to bear the function of reinforcing the slope to place the living area at the terrace ledge. Another option was to divide the total flow of development buffer recreational areas with abundant green spaces, to avoid reducing the level of landscaping because of the density.

5. Conclusions

In conclusion, it is necessary to say that in view of the foregoing, a large research interest is the design of the experiment the terraced housing on the former slope of slope areas with subsequent aerodynamic testing to study the aerodynamic characteristics of the active surface and buildings on it, given the system of gardening, landscaping, changes in elevation to find the optimal proportions in the structure, height and composition of buildings in terms of bioclimatic comfort. Despite the complexity of the design in the slope areas of their urban development at the moment is considered promising and relevant. The main problem is the complex aeration and temperature-humidity characteristics of such quarries, which can disrupt the bioclimatic comfort of potential development [17]. In this case, it is necessary to carefully study the geometric characteristics of the slope, as they directly affect the aerodynamic characteristics. Checking the geometry of the quarry for aeration characteristics should be tested experimentally both at the stage of pre-design analysis and already with potential development. Poddaeva O.I., Dunichkin I.V., Prokhorova T.V. made attempt to prognosticate the prospects for the application of the wind power potential assessment methodology and its possible application in the course of design of multi-component restructuring of residential buildings [18]. Also it is important to identify the most effective compositional technique to conduct a comparative classification of the existing types of slopes and compositional techniques and experimental ways to test every option on bioclimatic comfort [19]. You must also choose the type of residential homes for each version of the composition. The data obtained may be successfully used both in the construction of the grooves and to a difficult terrain. It is also should be noted that when building slope areas, it is necessary to take into account that the upper sections (bars) of the slopes are most exposed to wind, respectively, the buildings located on the upper terraces of the slope require additional measures for wind protection, for example with the help of green spaces. Also on the upper sections of the rational placement of wind turbines, which can partially provide energy to the building [20]. Myagkov M. S.,
Gubernskiy Yu. D., Konova L. I., and Litskevich V. K. claim that it is also necessary to take into account that it is necessary to choose the recesses of a sufficient width of the bottom, as this will contribute to the natural ventilation of the territory [21]. It is also necessary to adapt the buildings to the complex terrain by selecting certain types of buildings such as terraced houses or houses on stilts. These types of buildings allow to further strengthen the slope and contribute to aeration of the area. But in case of adaptation of buildings to a certain slope it is necessary to consider a possible lack of insolation solved by the device of atriums capable to give additional lighting and heating of the building.

The completion of the present study is the following algorithm for the use of the above methods:

- Determination of wind velocity and transformation flows on the slopes;
- Assessment of the territory for the placement of terraced buildings and conventional buildings, taking into account the wind regime;
- Development of town-planning measures for wind protection of buildings (location of atriums, landscaping, small architectural forms, adjustment of building composition);
- development of town-planning measures to improve the aeration of the building on the basis of the effect of temperature convection (location of shadow canopies, landscaping, arches and gaps between buildings, adjustment of building composition);
- Assessment of the bioclimatic comfort of terraces and slopes of slope areas.

The result of the study makes it possible to improve the quality of the environment and the safety of living in sloping areas.

References

[1] Cetin M, Adiguzel F, Kaya O and Sahap A 2018 Mapping of bioclimatic comfort for potential planning using GIS in Aydin Environment Development and Sustainability 20 (1) pp 361–375

[2] Chernih D V 2016 Landscape basis for the formation and optimization of the territorial organization of environmental management in the mountains (on the example of mountains of southern Siberia) News of Altai branch of the Russian geographical society 2 (41)

[3] Egorychev O O and Dunichkin I V 2013 Climate Projections for the Urban Environment in the Assessment of the Wind Energy Potential of Buildings Vestnik MGSU (Proceedings of Moscow State University of Civil Engineering) 6 pp 123–131

[4] Tregubova E A, Tagirova R S and Zubcov A N 2016 Principles of Building on Difficult Terrain Student and Science 11 pp 95–101

[5] Naboni E 2014 Integration of outdoor thermal and visual comfort in parametric design In 30th International PLEA Conference pp 1–10

[6] Poddaeva O I, Dunichkin I V and Prokhorova T V 2013 Effect of Spatial Organization Patterns of Restructured Residential Housing Areas on the Wind Energy Potential of the Environment Vestnik MGSU (Proceedings of Moscow State University of Civil Engineering) 2 pp 157–165

[7] Grosso M, Chiesa G and Nigra 2015 Architectural and Environmental Compositional Aspect for Technological Innovation in the Built Environment Pubblicazione vol 10 pp 1572–81

[8] Oliveira S and Andrade H 2007 Int J Biometeorol 52 p 69

[9] Lazareva I V and Olenkov V D 2012 Urban Development of the Disrupted Areas City and Town Planning 3 pp 34–43

[10] Poddaeva O I and Dunickin I V 2016 Numerical and experimental investigation of wind effects for residential complexes in Moscow Industrial and civil construction 4 pp 42–45

[11] Kovalenko P P and Orlova L N 1993 Urban climatology (Stroiizdat) p 144

[12] Kolbin D S and Olenkov V D 2011 A Study of the wind regime with the aim of aeration and windbreaks urban areas Bulletin of Perm national research Polytechnic University Construction and architecture 1 pp 36–39

[13] Goncharenko Y N and Demidova T A 2016 Issues of Housing Design in Complex Architecture and design: history, theory, innovation 1 pp 148–152
[14] Serebrovsky F L 1985 *Aeration of populated areas* (Stroyizdat) p 172
[15] Poddaeva O I, Kubanin A and Churin P 2017 Architectural-construction aerodynamics *Litres*
[16] Olenkov V D 2017 Calculation of the Aeration Mode of Disrupted Areas *Bulletin of the South Ural State University Ser. Construction Engineering and Architecture* 17 (2) pp 13–19
[17] Suvorov V O 2014 Typology of Space-planning Decisions of Dwelling for Territories with Difficult Relief *Architecton Proceedings of Higher Education* 47 p 80
[18] Dolzhenkova E I and Kalashnikov D V 2015 Modeling of windproof structures *Journal of landscape architecture* 5 pp 32–36
[19] Dunickin I V, Poddaeva O I and Churin P S 2016 *Estimation of bioclimatic comfort city* (Izd-vo Mosk. state builds. un-ta)
[20] Ricci A, Kalkman I M, Blocken B, Repetto M P, Paula Ivens M and Freda 2015 A Local-scale forcing effects on wind flows in an urban environment *In Proceedings, International Workshop on Physical modeling of Flow and Dispersion phenomenon Physmod* pp 7–9
[21] Myagkov M S, Gubernskiy Yu D, Konova L I and Litskevich V K 2006 *Town, architecture, people and climate* (Publishing house Architecture-S) pp 77–80