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Architectural-planning and constructive structures of residential buildings and buildings on complex terrain

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Abstract. The article deals with the features of designing and improving the spatial and planning structure of the dwelling and residential development in conditions of complex terrain, taking into account orographic features of the structure and climatic conditions. The problem of developing a mountainous complex region is studied with the aim of developing the planning structure of residential units and the development of settlements, taking into account local climatic features of the terrain. Based on the study of the orographic relief structure, there was determined a classification of the relief in terms of form, types of planning structure of settlements, types of planning schemes for building up, as well as the structure of the dwelling depending on the indices of natural and climatic discomfort. The role of insolation in the regulation of micro- and eco-climates of complex relief has been identified. In connection with this, a typology of buildings constructed in various forms of a complex relief, as well as their space-planning and architectural-constructive solutions has been determined.

1. Introduction

In connection with the aggravation of the ecological and social situation in the mountain regions, there is a perceptible increase in public attention to the comprehensive study of the problematic chain "Mountains - City - People".

The purpose of this article is to find ways to create a comfortable micro- and ecological environment for housing development and residential buildings by using architectural and landscape features of the construction site with a complex terrain.

The mountainous areas occupy more than a third of the world's land surface. About 10% of the world's population lives in the mountains. In the CIS, the total area of the mountains is about 6 million km² or 26% of the total territory.

At the same time, a fairly large proportion of the population lives in areas from 500 to 1500m above sea level. More than 2/3 of the population lives in the mountain areas of Afghanistan, Ethiopia, Mexico and Peru, and 88% - in Bolivia.

In the CIS, mountain areas occupy very large territories. The mountainous landscape of the Caucasus, Pamir, Tien Shan cover the entire territory of Armenia (over 90%), Georgia (about 65%), Kyrgyzstan (over 75%), Tajikistan (about 93%), a large part of Azerbaijan, and also a part of Kazakhstan, Turkmenistan, and Uzbekistan republics. The extensive mountain areas are also found in Russia and Ukraine.

In recent years, due to the demographic growth of population, the need for land for settlement use, urban construction, and the development of the planning structure of the mountain-recreational complex has increased significantly.

The architecture and development of mountain areas require modern aesthetics and comfort of the environment, but the possibilities here are limited by the conditions of high seismicity, ground subsidence, terrain complexity, low accessibility to the territory, complexity of construction technology. Despite this, the limited and valuable land plots, the complexity of the terrain make it necessary to search for various compositional techniques for the rational use of the territory for planning the cities, towns and individual buildings.

With the development of urban buildings in the complex mountainous terrain zones and the formation of new microdistricts and their structures (facilities), it becomes necessary to take into account the impact of the degree of terrain complexity, i.e. its shape, intersection, both local microclimatic and ecological regimes. This affects the volumetric planning and architectural-constructive solutions for buildings, the placement of buildings and the volumetric-composition solution for housing development, planning acceptance, density of housing development, typology of buildings and, in general, the solution of urban-ecological problems.

The relief of the earth's surface is very diverse, but the variety of relief forms for simplifying its analysis is typified by a small number of basic forms, which are also applicable to architectural and construction design and the relief territory transformation for the urban planning purposes, housing development and building construction.

2. The formulation and method of solving the optimization problem

According to the orographic features and scale of the structure, the forms of relief for potential construction purposes are divided into the largest (mega-relief), large (macrorelief), medium size (mesorelief), small (microrelief) forms, which made it possible to reveal their urban development potential for the further development (see table 1).

Table 1. Forms of relief for potential construction purposes

Dimensions	Forms of relief			
	Largest (mega-relief)	Large (macrorelief)	Medium size (mesorelief)	Small (microrelief)
Horizontal	Tens and hundreds of thousands of square kilometers	Hundreds of thousands of square kilometers	Hundreds of thousands of square kilometers	Meters and hundreds of square meters
Vertical	Hundreds and thousands of meters	Hundreds and thousands of meters	Meters, less than tens of meters	Meters, less than tens of meters
Examples of forms	Mountainous regions, highlands, vast hills and lowlands	Separate mountains, mountain ranges, large river valleys, intermountain depressions,, hollows	Hills, ravines, barchan chains	Hills, mounds, gullies
Urban development	The structure of entire countries, cities, towns.	Medium and small cities, settlements	Medium and small cities, settlements	Settlements, buildings and complexes

The practice of construction shows that the shape of the terrain, the nature of the slope of the site and its microclimate make the greatest influence on the location and organization of the planning structure of towns and settlements as well as the housing development. According to the developments of V.R. Krogius [1,2] in the field of geomorphology, the formation of the relief is conditionally divided into several orders of magnitude. With reference to the solved problems on our side, the following types of relief are noted: microrelief - small individual forms or elements of relief; mesorelief - large individual forms and complexes of various forms of relief.

There are various building classifications of the relief territory depending on the slopes. For the purpose of urban development of a complex relief, the Central Research Institute of Urban Planning has developed a classification that covers large-scale territorial changes [3].

Based on the study of the domestic and foreign experience of urban development of the relief situation [4,5,6,7,8], we propose the following classification of relief in the form, which takes into account local climatic features of the territory and its suitability for architectural and construction development (see table 2).

Table 2. Classification relief forms

Relief forms	Definition	Degree of suitability for urban development
Hill	- a small hill	suitable
Mound	- an artificial hill	suitable
Ridge	- a hill, stretched in one direction and formed by two opposite slopes	suitable
Saddle	- a lowering between two neighboring mountain peaks or hills	suitable
Hollow	- a conical, closed from all sides deepening	suitable
Dell	- a hollow, tilted in one direction depression	unsuitable, suitability is limited
Valley	- a wide hollow with gentle slope	suitable
Gorge	- a narrow hollow with large chips	suitability is limited
Terrace	- a natural horizontal or slightly inclined platform of different origin on the mountain slopes	suitable
Mountain	- an elevation of conical shape	suitability is limited

3. Results of optimum design

In order to assess the complex terrain for urban development at the initial stage of design and survey work, a spatial program model of the relief territory was created.

For this purpose, at the initial stage of the study, a plan was developed for describing the relief territory for urban development needs, including the following positions:

1. Name of the territory.
2. General characteristics of the relief.
3. Forms of relief (relief model) and its elements on the described territory.
4. Orographic complexity of the relief territory.
5. Water substance in the relief territory.
6. Natural and climatic conditions of the relief territory.
7. Minimum and maximum height of the relief territory.
8. Minimum and maximum slope of the relief territory.
9. Exposition of relief and the nature of the slope of the territory, the insolation conditions.

10. Aeration conditions of the relief territory.
11. Susceptibility to landslide phenomena of the relief territory.
12. Susceptibility to mudflows of the relief territory.
13. Conclusion on the relief suitability for urban development needs.

At the next stage of the pre-project stage of the work, there were carried out the engineering-geological studies. Using the CredoTOPOPLAN software, a topogeographical scheme for the complex relief of potential construction was developed complex by means of digital software modeling of relief. This scheme includes two basic operations:

- creation of a relief model.
- maintenance of the model for the purpose of construction of buildings and their complexes, taking into account an amount of the local natural and climatic factors.

The relief models presented in three-dimensional form allow us to estimate relief surfaces, their lines and points, the combination of which builds three-dimensional forms of relief. The shape of relief for modeling purposes should be formated to the following general forms:  - valleys, gorges, elongated canyons with strict vertical or vertical slopes; **V**-valleys are gentle slopes; **U**-valleys with a wide flat bottom;  - hollows with gentle slopes;  - mountain; **Λ** - hill.

Practically, the forms of relief are considered depending on their complexity, bias, exposure, insolation condition and degree of ventilation and they are the territories for potential construction of buildings and their complexes, settlements and cities.

Analyzing the practice of urban development of a complex relief, it becomes clear that there is a gap in the field of urban-ecological research for cities differing with complex orographic situation, causing extreme low-wind and calm aeration conditions.

The cities located in the mountains are predominantly located in the mountain basin, so their air basin is slightly ventilated.

In the conditions of settlements, both cities and these zones are potential hotbeds of the greatest concentration of pollution by harmful and poisonous impurities, which makes them environmentally hazardous.

The complex relief is seen as the territory through which the anabatic warm air rises in the city during the day-time and the katabatic cool air descends at night, therefore the planning structure of the residential area should be organized taking into account this important local aerodynamic factor [9].

4. Discussion

The orographic features of the relief cause the formation of a system of local winds, of which the slope and mountain valley ones are most noticeable. The slope circulation is influenced by the mountain-valley circulation. The orographic and climatic differences have predetermined the planning decision for the housing development on a complex relief by drafting up the principles for the formation of the architectural-planning structure of the housing development and the structural design of the buildings.

On the basis of the study of the insolation condition of the exposure of the relief territory and the active structure of the housing development, a physical-mathematical model of the aerodynamic characteristics of the housing development in the mountain hollow form of the relief has been developed. It makes possible to determine the ways of predicting and regulating the microclimate and eco-climate of slope surfaces, as well as housing development and buildings built on the slopes and the bottom of the mountain hollow space.

Establishment of purposeful theoretical and experimental studies of the factors of micro- and ecoclimate made it possible to develop an effective method for calculating the natural aeration of housing development and buildings with various architectural-planning structures that are being constructed on a complex relief taking into account the conditions for their insolation. The role of insolation in the regulation of micro- and eco-climates of complex terrain has been revealed. In connection with this, a typology of buildings constructed in various forms of a complex relief, as well as their volumetric planning and architectural-constructive solution has been determined.

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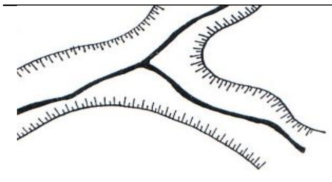
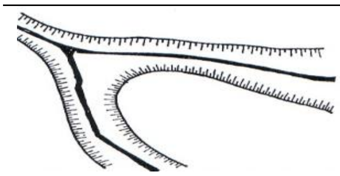
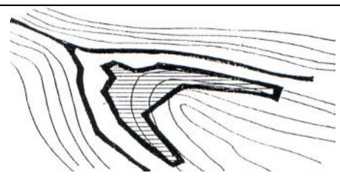
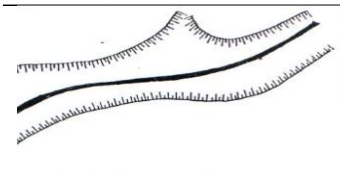
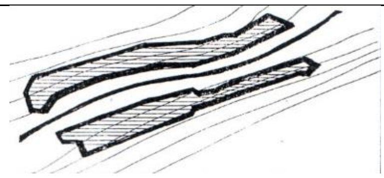
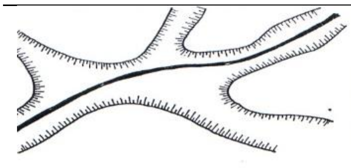
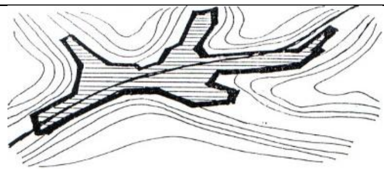
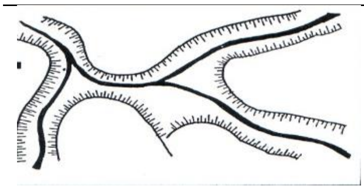
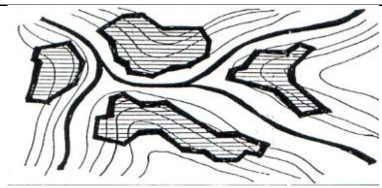
Analysis of a large number of settlements and buildings built on a complex terrain, taking into account the above conclusions, based on theoretical and experimental laboratory, in-situ studies of micro- and ecoclimatic factors, made it possible to formulate a series of solutions to determine the planning structure and housing development schemes and residential buildings (see table 3, 4, 5).

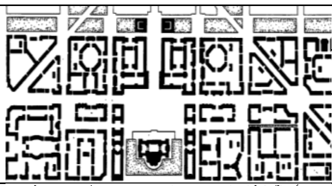
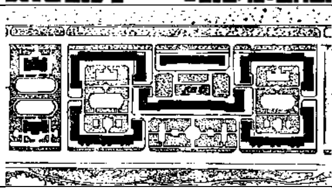
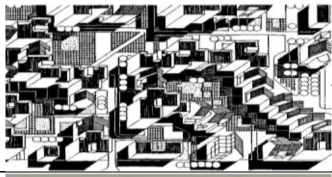
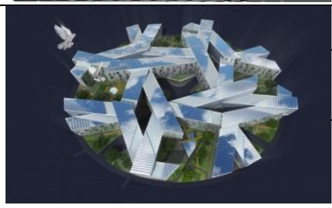
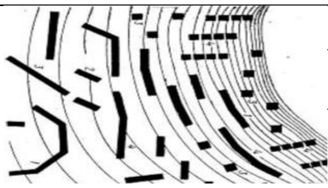
Table 3. Relief situation and type of planning structure of settlements

Relief situation	Type of planning structure	Planning layout of settlements
Settlements with compact planning structure		
		
Settlements with a radial planning structure		
		
Settlements with a linear planning structure		
		
Settlements with a ramified planning structure		
		
Settlements with a group planning structure		
		

The generalization of the characteristic features of the native mountain architecture and the analysis of the main directions for the construction of cities and settlements made it possible to classify the types of planning layouts of buildings built in conditions of complex terrain to determine the basic principles for modeling and integrating the space & volumetric forms of settlements and the structure of residential buildings (see table 4) .

Table 4. Classification of types of planning schemes of construction, erected in conditions of complex terrain

Type of structures	Number of storeys	Terrain development	Nature of relief (in complexity)		
			low	average	great

			complexity	complexity	complexity
Structure of detached buildings	increased		●	◐	○
	mean		●	●	◐
	small		●	●	◐
Intermittent structure	increased		●	◐	○
	mean		●	●	○
	small		●	●	○
Intermittent - continuous structure	increased		◐	○	
	mean		◐	◐	
	small		●	◐	
Continuous structure	increased		○	○	
	mean		○	○	○
	small		●	◐	
Terraced structure	increased		●	◐	○
	mean		●	◐	○
	small		●	●	◐
Blocked structure	increased		●	○	
	mean		●	◐	
	small		●	●	
Carpet structure	increased				
	mean		◐	○	○
	small		●	◐	○
Crystalline structure	increased		◐	○	○
	mean		●	○	○
	small		●	◐	○
Free structure	increased		◐	◐	
	mean		●	●	☾
	small		●	●	◐

Designation: ● - mass application, ◐ -limited application, ○ -application in individual cases

With the development of urban development in mountain areas and the formation of new microdistricts and their structures, it becomes necessary to take into account the impact of the degree of terrain complexity, i.e. its shape, intersection and micro- and environmentally friendly regime. The location of building construction, planning acceptance, density and composition of buildings, as well as typology of buildings, etc., depend from that.

Studying the landscape and climatic features and typology of the dwelling in the southern CIS region, the complex department of the Experimental Design branch of Tashkent Zonal Scientific Research Institute has taken into account the complexity of the orography of the Central Asian Republics and suggested the following classification of the landscape and climatic regions of the mountainous terrain, typical for Gissar-Alai, Pamir, Tien-Shan mountain systems, as well as the Caucasus mountain system [10]. The classification also took into account the results of the large-scale meteorological studies of the research team, with the author himself as a team-member.

Low altitude (LA) - height up to 1000-1300 m above sea level, IVA and IVG climatic subareas in the State Building Regulations, summer is the typological period.

Medium altitude (MA) - height 1000-1800 to 2200m above sea level, IIIB and IIIB climatic subareas in the State Building Regulations, summer and winter are the typological periods.

Highlands (HL) - over 2000-2200m above sea level, IIB and IB, climatic subareas in the State Building Regulations, summer and winter are the typological periods.

With the aim of typifying the features of the natural and climatic conditions of the complex relief of the southern CIS region to the purposes of typifying the dwelling on the basis of the altitude-landscape-climatic characteristics of the territory, were identified the following (vertical) zones and situations typical to the Central Asian and Transcaucasian republics:

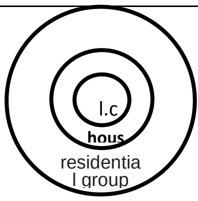
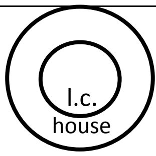
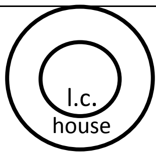
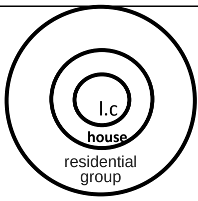
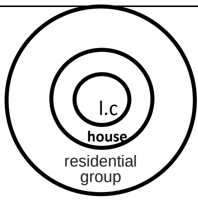
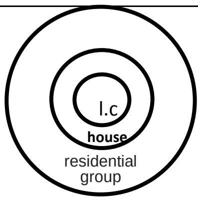
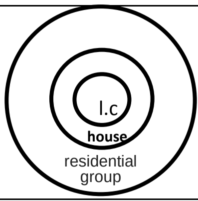
- zone of overheating conditions – IV-lowlands (A, B and C subareas)
- zone of optimal conditions – IV- midlands (A and B subareas)
- zone of intermediate conditions – IV- midlands (B and D subareas)
- zone of special conditions – IV-highlands (A, B and C subareas)

The main characteristics of the zones of optimal, intermediate and special conditions in the areas of the midlands and highlands have determined a differentiated approach to the design, construction and operation of the dwelling in each of the zones in accordance with the altitude-landscape-climatic situations, as well as requirements for different types of housing for each zone corresponding to the volume-planning and constructive structure.

The structure of the dwelling, depending on the indices of natural and climatic discomfort in the midland- and highland conditions, is solved in a three-level or two-level version. The three- level version of the dwelling consists of the following space & volumetric levels: a residential group, a dwelling house, a living cell; two-level consists of an apartment house, a living cell (see table 5).

Table 5. Types of interaction of different levels of residential structures with the external environment

Zone, subregion, situation type, level of residential structures	Number of levels included in climate-forming housing	Relationship between structure of a residential group and external environment	Relationship between structure of apartment house and cell with external environment

Zone of optimal conditions, IVMA, A-situation, three-level		- semi-open mode of operation - in the daytime: protection from high valley winds / at night: access to cool mountain winds	-adjustable - in the afternoon: closed mode / at night: open mode for ventilation and cooling purposes
Zone of optimal conditions, IVMA, B-situation, two-level		- open mode of operation - open contact with the environment during the day	- adjustable - in the daytime: alternation of closed and open modes / at night: open mode for ventilation and cooling purposes
Zone of intermediate conditions, IVMA, B-situation, two-level		- open mode of operation - open contact with the environment during the day	- open - open contact with the environment during the day
Zone of intermediate conditions, IVMA, G-situation, three-level		- semi-open mode of operation - in the daytime: access to warm valley winds / at night: protection from cool mountain winds	- open – adjustable - in the daytime: open mode / at night: open or closed mode
Zone of special conditions, IVHL, A-situation, three-level		- semi-open mode of operation - in the daytime: access to warm valley winds / at night: protection from cool mountain winds	- adjustable mixed - in the daytime: open mode / at night: closed mode with- or without heating
zone of special conditions, IVHL, B-situation, three-level		- closed mode of operation - protection from cold winds during the day	- mixed - closed - in the daytime: open or closed mode without heating / at night: closed mode with heating
zone of special conditions, IVHL, B-situation, three-level		- closed mode of operation - protection from cold winds during the day	- closed - closed mode with heating

5. Conclusion

Summing up the conducted studies we should note that when designing a single complex or detached buildings, it is recommended to use separate prospective methods and solutions of a native dwelling traditional for the given zone, with appropriate adjustments that take into account the requirements of a modern space-planning and architectural-constructive solution of the structure of housing development and buildings, as well as the natural and climatic conditions of the area:

- use of techniques to maintain, intensify or reduce wind flows through the positioning of the multi-storey buildings, the rational planning of canyons of development, the use of various types of air entrappers, air ducts and air control devices.
- creation of local winds of thermal origin in housing development and in buildings by purposeful use of the mechanism of interaction of insolation with an active building surface.
- use of methods of interchangeability of buildings and territories by arrangement of dense housing development, with obligatory maintaining of a comfortable microclimate.
- use of deeply echeloned structure of the dwelling, especially a group one.
- choice of the shape of the square-like plan of a building.
- provision for the structure of a buried dwelling, leading to an area reduction of the outer walls, which contact with the cold outside air.
- concentrate the main premises of the dwelling in such a way that the surrounding auxiliary rooms could play a role of a heat vestibule.
- application of top lighting (light lamps) in living premises, allowing to build up “the depth” of the building and provide insolation and day light.
- differentiation of the height of different premises depending on the functional and economic purposes.
- indoor zoning with the identification of different floor and ceiling levels within a single contour of the volume of the dwelling.
- use of methods of improvement and gardening of adjacent areas.

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References
[1] Krogius V R 1979 City and relief. Moscow: Stroyizdat p **124**
[2] Town planning on the slopes. 1988 Ed. by Krogius Y . Moscow: Stroyizdat p **328**
[3] Recommendations on the calculation of natural and climatic factors in the planning and improvement of cities and group systems of populated areas. 1980 M.: Central Research Institute of Urban Planning p **138**
[4] Gorniak L Use of a territory with a complex relief for residential development M.: Stroizdat, 1982 p **72**
[5] Calabin A V 2012 The house on a relief / Calabine A.B. - Ekaterinburg: Webster, p **160**
[6] Suvorov V O 2013 Typology of housing in a complex terrain in terms of slope-relative architectural and spatial layout. M: Fundamental and Applied Problems of Science: VIII Internternational simposium vol. 7
[7] Abbott D Pollit K 1980 Hill housing. London
[8] Saini B S 1962 Hausing in the hot arid tropics. "Architectural Science Review", vol.5, No.1
[9] Giyasov A 2004 Regulation of the microclimate of urban development in a hot calm climate. Abstract of the PhD in technical sciences thesis. M: p **67**
[10] Conduct scientific research and develop requirements for the development of the recreational facilities for construction in the landscape and climatic conditions of Tajikistan. 1980 Scientific Report. Dushanbe-Tashkent