



Relief, Protection and Climate in the Architecture of Mountain Peoples

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Abstract. Mountain village architecture of Azerbaijan is characterized by planning according to the relief, a step (terrace) construction system, and constructive engineering solutions. Houses are placed along the slope, follow the relief line, and are built with minimal interference to the soil layer. This approach reduces large excavations, minimizes the risk of landslides and erosion, and makes the construction process more economically efficient. Thick stone walls and supporting structures on the lower floors ensure stability, while light materials on the upper floors balance the load distribution. The back walls of some houses rest on the soil layer, providing thermal insulation and maintaining the stability of the internal temperature. Stepped construction and topographical planning also serve a socio-spatial function; multi-level spatial structure increases solidarity within the community, expands mutual control and security opportunities, and creates conditions for the formation of public and semi-public spaces. As a result, Azerbaijani mountain architecture demonstrates a model of sustainable living that integrates engineering, ecological, and social aspects and constitutes an example for modern sustainable architectural concepts.

Keywords: Azerbaijani mountains, mountain architecture, stepped construction, relief line tracing, efficient land use, stone wall construction, erosion and landslide risk

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1. Introduction

Residential spaces formed in the mountainous areas of Azerbaijan are not only the result of construction techniques or household needs, but also a complex product of socio-cultural development, economic activity, and interaction with the natural environment lasting for millennia. These living models emerged as a material expression of man's struggle for survival in harsh geographical conditions. The architectural examples formed in the mountain environment are a real indicator of the balance, adaptation, and interaction between man and nature.

The Greater Caucasus and Lesser Caucasus mountain systems, which cover an important part of the territory of Azerbaijan, are not only geographical areas, but also important zones where cultural diversity and ethnic richness are formed. Architectural forms developed in mountainous regions constitute a significant indicator of the interaction between humans and the natural environment (UNESCO, 2023). Villages and settlements located along these ridges have developed in conditions of complex relief structure, steep slopes, deep valleys, slippery soil layers, and seismic activity. In the process of settlement, the limitation of land areas, the scarcity of arable land, and the uneven distribution of water sources had a direct impact on the planning of living. For this reason, spatial organization in mountain villages is not random, but the result of rational planning in accordance with natural and geographical conditions. The climate factor also played a decisive role in the formation of mountain architecture.



In mountainous areas, winter months are long and harsh, temperature differences are sharp, winds are strong, and snow cover is thick. These conditions require a special approach to the construction of houses. Thick walls, small windows, rooms with low ceilings, and the use of heat-retaining materials were intended to minimize heat loss (Abbasov et al. 2022). At the same time, the intensity of solar radiation and the problem of dryness in the summer season led to the formation of the shading system of buildings, balconies, and inner courtyards. Mountain architecture thus provides a traditional and tried-and-true model of climate adaptation (Mustafayeva et al. 2025). Communication and transportation difficulties also affected the structure of living spaces. In historical times, mountain villages operated mainly based on self-sufficiency; access to foreign markets was limited. Since it was impossible to transport heavy construction materials from long distances, mainly local resources were used. Local stone, pieces of river rock, wood, and soil mixtures formed the main material base of the construction. This has created an important advantage in terms of both economic efficiency and environmental sustainability. Many of the principles presented in modern times as "sustainable architecture" have been traditionally applied in mountain communities. The historical safety factor has a special place in the planning of mountain habitats. Mountain villages formed a defensive spatial structure under the conditions of foreign attacks, inter-tribal conflicts, and political instability at different times. The spatial organization and defensive planning principles in mountain villages have been closely associated with historical security needs and the social structure. Proximity of houses to each other, narrow and winding street system, buildings built on high points, thick stone walls, and limited entry and exit points have been part of the collective security model. This structure not only provided physical protection but also strengthened social solidarity and a sense of mutual responsibility within the community. Thus, architecture here acted not only as an individual space, but as an indicator of collective identity and social organization. Another important feature of mountain architecture is that it does not conflict with the terrain but instead forms in harmony with the natural landscape. The architecture of mountain villages is built in harmony with the terrain and serves to protect the natural landscape. This approach also increases solidarity within the community and expands the possibilities of social control and security. Stepped house construction on sloping slopes, the roof of one house serving as the yard of another, construction of buildings with minimal intervention on the soil layer are examples of high adaptation from the point of view of engineering. This approach served to prevent landslides, reduce wind impact, and maintain energy balance. At the same time, the visual compatibility with the landscape created an aesthetic integrity. The socio-cultural aspect is also an integral part of mountain architecture. Activities such as family structure, economic activity, cattle breeding, and crafts have influenced the internal planning of space. The joint arrangement of living, household, and storage zones in houses has created functional efficiency. Yards and balconies acted as both domestic and social communication spaces. Thus, the architectural form has become an important mechanism that ensures the continuity of the social lifestyle. Constructive solutions aimed at energy efficiency in traditional mountain dwellings are consistent with the principles of sustainable modern architecture.

As a result, the architectural model formed in the mountainous areas of Azerbaijan is a complex synthesis of adaptation to the natural environment, social solidarity, and the need for security. This architectural tradition can be evaluated as a product of human ability to live in harsh geographical conditions, creative thinking, and collective experience. Architectural forms in the mountainous regions of Azerbaijan have been shaped by local climatic conditions, economic activities, and ethnographic traditions. In terms of modern architecture and urban planning, the experience of mountain communities is of great scientific and practical importance in terms of ecological sustainability, energy efficiency, and principles of harmony with nature. For example, the location of Khinalig in the context of the historical and architectural landscape required construction systems suitable for the terrain and climatic conditions. The mountain architecture traditions of the Caucasus influenced the formation of long-lasting architectural examples in ethnographic and cultural perspectives.

2. Principles of construction in accordance with the terrain

The main difficulty of the construction process in mountainous areas is the steep slope of the land surface, the instability of geological layers, and the risk of erosion and landslides (Mardanov 2022). In sloping areas, the thickness and bearing capacity of the soil layer are not the same; some parts are rocky, and some parts consist of loose and slippery rocks. This requires additional engineering calculations and constructive solutions during construction. Since traditional plain-type planning is not possible in the sloping terrain, the architectural form is built directly based on the conditions dictated by the terrain. The architectural model formed in the mountain villages of Azerbaijan is based on the principle of "not against the terrain, but with the terrain". Here, the sharp shape of the land is not considered an obstacle to be overcome, but a starting point for organizing the space. The buildings follow the direction of the slope, are placed according to the natural contours, and are built with minimal land intervention. This approach gives a more sustainable result from both an ecological and constructive point of view (Abbasov et al. 2022).



Figure 1. Guba Khinalig village. (Source: Laman Ismayilova).

Khinalig village is located at an altitude of more than 2000 meters above sea level and has an extremely complex structure in terms of relief (Figure 1). Khinalig is the highest, remotest, and most isolated village in Azerbaijan (Mustafayeva et al. 2025). There are more than 350 stone houses in the village; Although many of them were built two or three centuries ago, they are still inhabited. The village is built on a steep slope and is surrounded by deep ravines, rocky massifs, and exposed mountain ranges. This area is exposed to both strong winds and sharp temperature differences. In winter months, the snow cover is thick, and the freezing and melting of the soil layer affects the stability of buildings. Khinalig architecture is an engineering marvel: stone houses are built directly into steep mountain slopes, arranged in an amphitheater-shaped terrace system; the roof of a house becomes the yard of the house above. In such conditions, the arrangement of living spaces is not only a question of architecture, but also a question of engineering and adaptation to the natural environment. In high-altitude mountain villages such as Khinalig, the adaptation of buildings to the terrain and the use of local materials are among the key characteristics of architecture.



Houses in Khinalig are built step by step, that is, on the terrace principle. Khinalig houses are built of river stones and have a unique terrace structure; the roof of one house acts as the backyard of the next house. Due to the harsh climate, limited building space, and strong winds, the buildings are closely spaced. Mountain village architecture of Azerbaijan is based on the principles of planning and terraced construction. In the village of Khinalig, houses are placed along the slope and built following the relief line; this approach minimizes soil excavation and reduces the risk of landslides (Aliyeva 2024; UNESCO World Heritage Centre 2023). Each building is located on a certain part of the slope, and its lower part rests on the soil layer. The cultural landscape of the Khinalig people preserves its originality in terms of its forms, materials, uses, traditions, and intangible heritage (University of Massachusetts Amherst Center for Heritage & Society 2024).

This system provides several important advantages:

- The natural stability of the slope is preserved, and there is no abrupt cutting of the soil mass;
- Houses partially protect each other from wind and cold air currents;
- Limited land area is used to the maximum.

As a result of the stepped structure, the roof of a house functions as a yard or passageway for the house above. This multi-layered spatial use is both functionally and socially significant. The preparation of roof coverings with a soil and clay layer makes it possible to move on and, at the same time, strengthens thermal insulation. Thus, the roof is not only a covering element but acts as an extension of the living space. Another important aspect of the principle of construction according to the terrain is the minimization of soil excavation. In mountain villages, wide platforms are not created; on the contrary, buildings are placed on the existing natural surface. This reduces labor and material consumption and minimizes the risk of slipping. Since there is no major land intervention, the hydrological regime of the slope - that is, the flow direction of rain and snowmelt - is not seriously disturbed. Structurally, thick stone walls are used at lower levels. The stone material "fixes" the building to the ground with its weight and provides stability in contact with the ground. In the upper parts, lighter constructions are used, which balance the load distribution. The back walls of some houses lean directly on the slope, and the soil acts as a natural heat insulator. As a result, the temperature of the interior remains more stable. But despite all these adaptation mechanisms, the mountainous terrain creates several difficulties. Transporting construction materials along the slope requires a lot of physical labor. Heavy rains and misdirected snow runoff increase the risk of erosion and landslides (Mardanov 2022). Laying modern communication lines - water, sewage, gas, and electricity networks - requires complex engineering solutions. Seismic activity also necessitates additional structural reinforcement. In mountain villages, the stepped construction system not only increases structural stability but also strengthens the social function of the place; the roof of a house serves as a courtyard or passageway for the house above.

However, mountain villages that have been preserved for centuries prove that the principle of building according to the terrain is a sustainable and efficient model. This architectural form creates visual harmony with the landscape, minimal interference with the natural environment, and forms an energy-efficient system. The basics of the approaches presented in modern architecture, such as "contextual design" and "sustainable planning," have been traditionally applied in the mountain villages of Azerbaijan. Architectural features and material selection in Azerbaijani mountain villages have been developed in accordance with local climate and relief conditions. Stone building traditions provide engineering and environmental sustainability, enhancing the socio-spatial aspect (Maclachlan 2008).

Stepped (terrace) construction systems and following the relief line were among the main principles in the formation of Azerbaijani mountain architecture. In mountainous areas, the slope of the land surface, the instability of rocks, and the risk of erosion and landslides have directed the planning of residential areas in



a completely different direction than in plain areas. Since it is difficult both technically and economically to create wide and smooth platforms under these conditions, the construction tradition has developed by adapting to the natural terrain (Mardanov 2022). In Azerbaijani mountain villages, houses are arranged in steps along the slope, and each building is built on a unique terrace at a certain level. As a result, the village acquires the character of a multi-level composition and creates a single architectural ensemble with the landscape. In mountainous areas such as Sheki and Guba, all villages are terraced down the slope; houses and gardens are interconnected to maximize arable land.

The stepped system primarily provides structural stability. The lower part of the houses rests directly on the soil layer or rocky surface, and the thick stone walls increase the stability by lowering the center of gravity of the building. This method strengthens the resistance to soil pressure and reduces the risk of landslides. In traditional mountain architecture, extensive excavations are avoided, and the natural contour of the slope is preserved to the maximum extent. A sharp intervention in the soil layer can disrupt the geological stability of the slope and create a long-term danger. Therefore, the buildings are built following the direction of the natural surface, and the relief acts as the main guiding element of the architectural composition. Efficient use of land is one of the important advantages of this system. In mountainous areas, flat areas suitable for cultivation and living are limited. As a result of the staggered planning, each level becomes a separate usable space, and there is almost no free space left. This dense and compact structure reduces distances within the village, intensifies social ties, and creates efficiency in terms of communication. At the same time, it allows the protection of arable land areas. Thus, the architectural solution is not only a construction problem, but also a matter of maintaining the economic and economic balance. The stepped construction system also serves to reduce erosion (Mardanov 2022). Each building partially limits the movement of the soil mass at its level and, in a certain sense, performs the function of a retaining wall. This constructive solution helps to stabilize the slope during the flow of heavy rain and snowmelt water. In some cases, additional stone pillars and retaining walls are built at the bottom of the houses, which prevent landslides. The houses are arranged in steps, adjacent to each other along the slope; the flat roof of one house becomes the terrace of the next. Such engineering solutions are formed because of long-term experience and maintain balance with the natural environment. One distinctive feature of this system is that the roof of a house functions as a yard or passage space for another house located on the upper level. Roof coverings are usually made with a layer of earth and clay, which both improves thermal insulation and makes it possible to move on it. Thus, the roof is not only a protective structural element but also acts as an open space where daily household activities and social communication continue. This multi-layered spatial use enhances interaction within the village, strengthens neighborhood relations, and supports a collective life model. The use of stone walls in the architecture of Khinalig provides both engineering stability and increased thermal insulation, thus maintaining internal temperature stability in harsh winter conditions (AZERTAC, 2016).

The principle of tracing the relief line is one of the main features of Azerbaijani mountain architecture. Buildings and streets are built according to the natural direction of the slope; rigid and artificial straight lines are avoided. This approach preserves the ecological balance by minimally interfering with the soil layer and ensures the natural flow of rainwater. As a result, the hydrological system is not disturbed, and the risk of erosion is reduced. At the same time, the village becomes an integral part of the landscape and creates visual harmony. From a distance, mountain villages seem like a continuation of the natural environment.

All these features show that the stepped construction system and following the relief line is not a random choice in Azerbaijani mountain architecture, but a rational and sustainable model of adaptation to natural-geographical conditions. This model demonstrates high efficiency in terms of structural stability, efficient use of land, and social-spatial organization. The principles presented in modern architecture as "sustainable design" and "contextual planning" have been traditionally applied in the mountain villages of Azerbaijan for centuries (MacLachlan 2008). Thus, mountain architecture is a bright example of a harmonious and



sustainable living model created by people by adapting to their conditions without conflicting with nature. Following the relief line is considered one of the main principles in Azerbaijani mountain architecture, and this approach ensures both the safety and economic efficiency of buildings. In mountain villages, houses are built following the relief line; that is, the natural descent and ascent direction of the slope is preserved, and no artificial flat platforms are created. This directly affects the construction process and creates several important advantages. First, the need for large-scale excavations is reduced. Since construction is carried out according to the natural contours of the slope, extensive cutting or transportation of the soil layer is not required. This approach both reduces construction costs and maintains the geological stability of the slope.

Second, following the relief line minimizes the risk of slipping and collapsing. Soil layers in mountainous areas are often unstable, and the creation of artificial platforms can destabilize the soil. And construction according to the natural relief allows for maximum use of the natural stability of the soil layer, so the houses remain stable for a long time.

Thirdly, this approach makes the construction process more profitable from an economic point of view. Since the natural forms of the slope are preserved, the need for additional excavation works, soil transportation, and the construction of additional supports is reduced. This creates efficiency in terms of time, labor, and money. In general, the principle of following the relief line not only creates technical and economic advantages but also ensures the aesthetic and ecological sustainability of mountain villages. When the houses are placed according to the natural contours of the landscape, the villages are harmoniously integrated into the mountain environment; there is no conflict with nature and long-term sustainability is maintained. This principle is one of the traditional features of Azerbaijani mountain architecture and is important from the engineering, ecological, and cultural point of view.

Special structural solutions and engineering approaches are applied in mountain architecture to ensure the stability of buildings on sloping terrain. In mountain villages, thick stone walls are built in the lower part of the houses, which ensures the stability of the structure at the point of contact with the ground. The weight and density of the stone help the building stand firmly on the slope and at the same time increase resistance to soil pressure. This approach is especially vital in mountainous areas where there is a high risk of geological instability and landslides. The architectural practice developed in mountain villages is an example for modern sustainable architectural concepts because it combines nature, engineering, and socio-cultural aspects. Lighter materials are used on the upper floors, which balances the distribution of the load of the house and reduces the risk of deformation of the building. This approach is both rational from the point of view of engineering and allows the creation of long-lasting buildings. In some cases, the back wall of the houses rests directly on the soil layer. This wall not only performs a reference function but also plays the role of thermal insulation. The soil acts as a natural insulator and stabilizes the temperature of the interior space. As a result, houses remain relatively warm from the inside even in harsh winter conditions; energy consumption and heat loss are minimized.

Thus, structural solutions in mountain architecture are the result of traditional engineering practices adapted to the complex conditions of the terrain and ensuring both physical stability and energy efficiency. This approach has formed long-lasting, safe, and ecologically sustainable architectural examples of Azerbaijani mountain villages. In Azerbaijani mountain architecture, stepwise construction and planning according to the relief is not only a technical and constructive approach but also has a deep impact on the socio-spatial aspect. In mountain villages, the gradual placement of houses along the slope, the arrangement of streets and passages according to the relief line, not only ensures efficient use of land and stability; it also creates optimal conditions for organizing community life and strengthening social relations.

The dense and multi-level spatial structure increases solidarity within the community. The proximity of the houses to each other and the formation of the passage and yard functions on the roofs intensify the interaction between the neighbors. For example, in the village of Khinalig, the roof of the upper floor serves as both an open space and a daily communication space for the house located on the lower level. This allows



the villagers to carry out their daily activities without being far from each other, as well as the creation of a social control mechanism. The staggered construction also increases mutual security capabilities. Since most of the mountain villages are in harsh terrain and complex environmental conditions, community members can see each other visually; roads and roofs are connected to each other, allowing for quick response in the moment of danger. This system also ensures the safe movement of children, the elderly, and animals, and strengthens the collective protection mechanism within the community.

In addition, stepping up construction creates conditions for the formation of public and semi-public spaces. Rooftops, terraces, and hillside open spaces serve both private use and community activities. For example, during the winter months, roofs can be used for snow removal or partial animal housing, and during the summer months, they serve as outdoor meeting and gathering areas. These multi-functional spaces provide flexibility and continuity of community life and help preserve socio-cultural traditions. Thus, stepwise construction and tracing the relief line in Azerbaijani mountain architecture do not consist only of engineering and ecological principles. It is also an important indicator of socio-spatial organization, ensuring community solidarity, security, and cultural continuity. This traditional approach can also serve as an example for modern sustainable architectural concepts, as it combines the principles of harmony with nature, social integration, and economic efficiency.

3. Conclusion

The analysis of the data presented on Azerbaijani mountain architecture shows that construction in mountain villages is not only an aesthetic and functional approach, but also a complex integration of engineering, ecological, and social principles. The main results can be summarized as follows:

First, construction according to the terrain and the stepped (terracing) system are the main elements that ensure the stability of mountain villages. The houses are placed in steps along the slope, planned according to the relief line and built with minimal interference with the soil layer. This approach reduces the need for large excavations, minimizes the risk of landslides and erosion, and makes the construction process both technically and economically efficient.

Second, constructive solutions and engineering approaches ensure the longevity of houses in complex terrain conditions. Thick stone walls are used in the lower parts, and lighter materials are used in the upper floors. The back walls of some houses rest directly on the soil layer and perform the function of thermal insulation. This system maintains internal temperature stability in harsh winter conditions and improves energy efficiency. Third, the socio-spatial aspect is an important component of the tiered system and terrain-friendly planning. The multi-level and dense spatial structure increases solidarity within the community, expands the possibilities of mutual control and security, and creates conditions for the formation of public and semi-public spaces. An organically developed network of ancient roads, temporary pastures, shrines, and mosques reflects a sustainable eco-social system adapted to extreme environmental conditions. Examples such as Khinalig village show that the multifunctional use of roofs and terraces strengthens community life, ensures social integration, and helps preserve cultural traditions.

As a result, Azerbaijani mountain architecture is a harmonious combination of terrain-appropriate construction, constructive solutions, and socio-spatial principles. This architectural model not only provides engineering and environmental sustainability but is also important in terms of organizing community life and preserving cultural and household traditions. This traditional practice is a model for modern sustainable architectural concepts, as it combines harmony with nature, social integration, and economic efficiency. The main point to be emphasized is that mountain architecture is a bright example of a harmonious and sustainable living model created by man without conflicting with nature and adapting to its conditions.



Author's contribution

The sole author is responsible for conceptualizing, collecting, and analyzing data, and writing and editing the manuscript.

Conflict of Interest

The authors declare no conflicts of interest.

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