Site layout as a function of shading in Karst region

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ABSTRACT

In built environment assured access to sun is important because of the quality of life and because of the energy benefits. We can find a great number of historical precedents of respecting this issue. In Slovenia traditional settlements of the Karst are a model example.

In this paper we investigated the Karst settlement of Kobjeglava. We studied the disposition of buildings with respect to cooling. We used the solar volume method for assessing the urban plan and estimating the solar access. The investigation was carried out with the newly developed computer tool, which is designed as an upgrade of the CAD program. It was developed by the Chair for Buildings and Constructional Complexes at the Faculty of Civil Engineering, University of Ljubljana.

In the course of our research we found out that in the treated cases the main influential factor of shaping settlements is the winds. As far as the topography, space and social organization allow it, the 15° incidence angle is used for solar heating during winter. The building dispositions do not offer much shading during summer. In front of residential parts pergolas are used. Protection against heat is also provided by the structure of the building envelope.

1. INTRODUCTION

Sun gives form to architecture. This simple truth is reflected in the architecture throughout the Mediterranean, on the level of building and on the level of urban plan. Ancient cities in the Mediterranean were built with respect to the sun. Solar rights also found their place in the Roman law. To make the best use of solar energy, urban plan has to ensure solar access to everyone when it is needed and shelter from it, when it is disturbing. In Slovenia traditional settlements of the Karst region are a model example.

Karst is the southwest region of Slovenia (Fig. 1). The sub-Mediterranean climate results in warm summers with prevailing southwestern wind and cool winters with strong northeastern wind called Burja. Since the country is formed of porous limestone, the water sources are scarce, with only few, in some parts none, surface streams. The architecture reflects such an environment both on the level of the building and on the level of the site disposition and urban planning.

In Karst there appear two main types of buildings arrangement, the linear and the nucleus arranger around a courtyard. The settlements positioned on south oriented sloped terrain usually use linear disposition. The terraces run from east to west, creating barriers to the northeastern wind and making the most of the southern solar exposure. During summer, western breeze coming from the sea helps to cool the houses (Fig. 2). The second type can be found on flat terrain. Buildings belonging to one

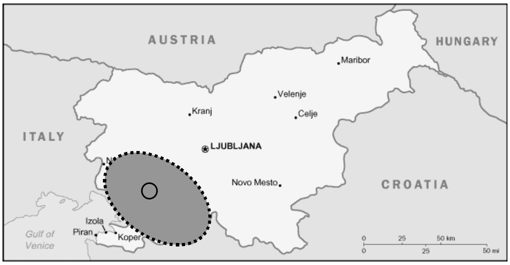

Figure 1: Plan of Slovenia showing the position of the Karst region and the location of the analyzed settlement.

household are positioned around a closed courtyard. In some settlements we find combinations of both types. We analyzed the second type of disposition, on the case of Kobjeglava.

Previous investigations (Krainer, 1993; Kristl and Kraiiner, 2000) showed that the 15º solar incidence angle is the lowest acceptable angle for our latitude (44º - 45º N), if we want to assure evenly distributed solar access during the heating season. We found out that in the treated cases, as far as the topography, space and social conditions allow it, the 15° elevation angle was used. This incidence angle occurs at 10.a.m. and 2 p.m. during the 21st of December when the sun is lowest. This means that at least 4 hours of insolation are assured during all winter. For the summer months, when overheating is due to occur, we checked the possible shading by neighboring buildings, positions of pergolas and stratification of air.

2. DESCRIPTION OF THE METHOD AND THE TOOL

For the early stages of urban design many authors suggest the analyses with the solar envelope method. R.L. Knowles (2003) proposed the method for assuring solar access to buildings. Many authors suggest computer aided calculations of solar envelopes (Yezioro and Shaviv, 1994; Capeluto and Shaviv, 2001; Arumi, 1979; Cotton, 1996; DeKay, 1992; Schiller and Uen-Fang, 1993).

The solar volume limits the development within the imaginary volume, which results from the sun's incidence angles. The method enables us to determine the maximum possible volume that can be built on a certain site. Buildings designed within the volume will not shadow the neighboring buildings or land.

Figure 2: South view of Štanjel.

The peak of the envelope is the top of a vertical gnomon. The north angles of the envelope (and the north edge) are determined on the basis of the shadow cast by the gnomon, when the sun has the minimum chosen elevation (for instance in the morning and in the afternoon of the winter solstice). The south edge of the envelope is determined by the parallel projection of the north edge through the base of the gnomon.

The investigation was carried out with the newly developed computer tool, which is designed as an upgrade of the CAD program. The computer tool was developed by the Chair for Buildings and Constructional Complexes at the Faculty of Civil Engineering, University of Ljubljana (Krainer et al., 2005).

The starting point is the site, with optional shape. The terrain can be horizontal or sloped in any chosen direction. The maximum slope towards the north is limited and cannot be larger than the incidence angle of the sunbeams. In this way we avoid theoretically endless solar envelope. The envelope is generated as a section of geometrical bodies, determined by incident sunbeams, passing through the top of a gnomon and limited by the dimensions of the site. The pyramid-like part of an envelope can begin on the terrain or can be raised above the ground level. In this way we can simulate urban environments where a selected number of floors above the ground level have different requirements as far as insolation is concerned. The program also offers the option of generating solar envelope across the boundary lines of a site. With this option we can acquire data about the area of influence of a certain building disposition or solar incidence angles. An optional number of buildings can be added to the site. The buildings can have different shapes and different roof pitches. The results are recorded as a dwg or a bmp file types and can be the base for further work.

3. ANALYSIS AND DISCUSSION

The Kobjeglava settlement is positioned on a plain in the central part of Karst. This is somewhat untypical choice of the terrain, which does not bring limitations or advantages.

The morphology of the Karst settlements and the houses are the product of:

- climatic influences (cold northern winter

wind and the summer heat).
- defense (protection of scarce water sources and harvest).
- social structure (land ownership and inheritance).
- sociological influences (privacy and contacts).

The strongest influence on the design of the settlements has the wind (its direction and times when it appears). The houses are closed towards the unpleasant northeastern winds and open towards sunny southern side. They form strings of rows, each house and row offering protection and shelter to the next one (Fig. 3). The typical dimensions of houses are 4-6 meters in depth and 6 meters in height. The roof pitches are low.

We observed two typical situations during the year when the sun’s path is considered:

- winter insolaton between 10 a.m and 2 p.m. (solar heating)
- summer insolation (between 11 a.m. and 1 p.m. (shading) and between 3 p.m. and 6 p.m. (danger of overheating)

We analyzed three typical nuclea formed of terraced buildings partly residential and partly outhouses (Fig. 5). Each nucleus belongs to one household, sometimes enlarged with families of the next generation. A typical nucleus forms a unit in itself. The residential buildings are positioned to the north of the block, forming a barrier to the unpleasant northern wind, with scarce or no windows in the north wall and opening into the courtyard. Along the sides and on the north part outhouses are positioned, forming a closed courtyard. In Kobjeglava the residential buildings are oriented mainly toward south. Similar situation occurs in all the settlements of this typ; the photo below was taken in the settlement Kobdilj (Fig. 4).

During the winter the insolation of the upper part (first floor) of residential buildings is provided. During summer afternoons the neighboring buildings (especially the ones positioned on the west side of the court) are not used for shading. The majority of courts are even open to the west. This brought us to conclusion that the use of summer breeze from the sea is one of the most important cooling strategies. Pergola in front of residential part is used for shading during the midday period. Cooling is enhanced by the architectural concept of buildings with massive stone walls with small openings, which accumulate surplus heat.

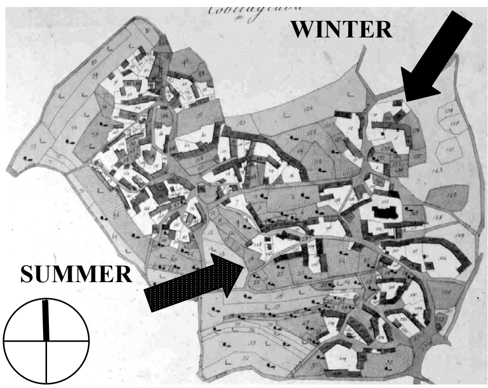

Figure 3: Plan of Kobjeglava, Franciscan land register, 19th century, with prevailing directions of winter and summer winds.

Figure 4: Entrance into a courtyard in Kobdilj.

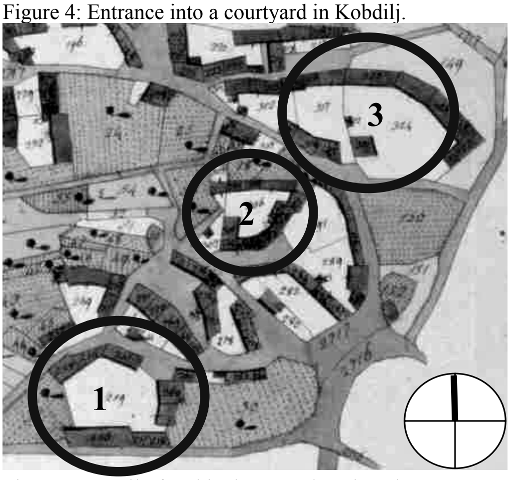

Figure 5: Detail of Kobjeglava; analyzed nuclea are marked with a circle and a number.

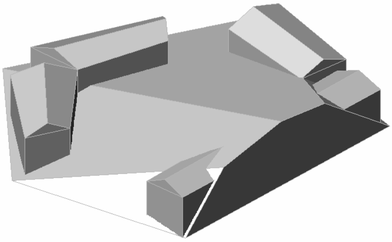

Figure 6: Nucleus No.1, Iso-metric view from the south-west; example of solar envelope on 21st of December between 10 a.m. and 2 p.m.

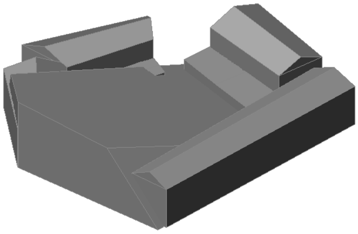

Figure 7: Nucleus No.1, Iso-metric view from the south-west; example of solar envelope on 21st of June between 3 p.m. and 6 p.m.

3.1 Nucleus No.1

We can see that during winter in the morning and afternoon time only the upper part of the residential building is insolated. The whole building is exposed to the sun between 11 a.m. and 1 p.m. The same situation can be observed on the iso-metric view below (Fig. 6).

The nucleus is completely open to the west. During summer afternoons the sun can unobstructedly shine into the courtyard. Pergolas shade the ground-floors of the residential buildings. The western side of the court, which is open is due to cooling effect provided by the southwestern wind, which blows during summer afternoons from the sea (Fig. 7).

3.2 Nucleus No.2

Nucleus No. 2 is the smallest unit of the studied examples. It repeats the pattern of the aerodynamic wedge to the northeast, open space to the south and interrupted ring around the court in the western part. We can observe the summer sun shining into the court during afternoons. Pergola in front of residential building provides shading of the ground floor. The influence of the afternoon wind is strictly taken into account (Fig. 8, 9).

3.3 Nucleus No.3

This nucleus presents the north border of the settlement, which can be observed in careful positioning of buildings, completely closed to the north and with no openings to that side. The winter solar envelope shows that south from residential buildings all objects are inside the volume, which means they do not cast shadows on the residential buildings during defined period of time. During winter the insolation of residential buildings in the ground-floor lasts two hours around noon. The upper floor receives longer solar exposure, four hours around noon (Fig. 10).

The summer afternoon envelope shows that the objects south and west of residential buildings are inside the volume. The positioning of buildings does not aloow mutual shading during that time. Shading of residential buildings in provided locally, with pergolas (Fig. 11). The nucleus is again open toward west, to capture the southwestern wind.

Urban plan of Kobjeglava clearly shows that the main influential factor is the wind. The houses form typical Karsic patterns formed of lines of houses closed toward northeast and

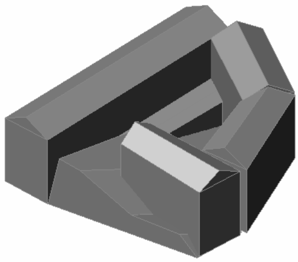

Figure 8: Nucleus No.2, Iso-metric view from the south-west; example of solar envelope on 21st of June between 3 p.m. and 6 p.m.

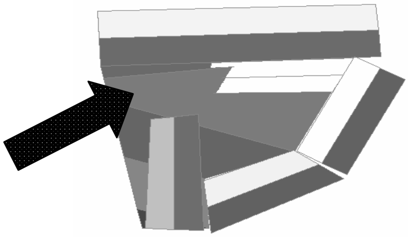

Figure 9: Nucleus No.2, top view; example of solar envelope on 21st of June between 3 p.m. and 6 p.m. The southwestern wind blows from the sea during summer afternoons and cools the buildings.

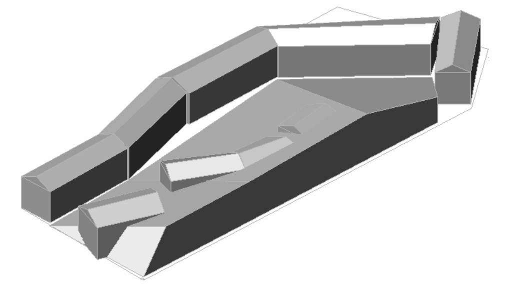

Figure 10: Nucleus No.3, Iso-metric view from the southwest; example of solar envelope on 21st of December between 11 a.m. and 1 p.m.

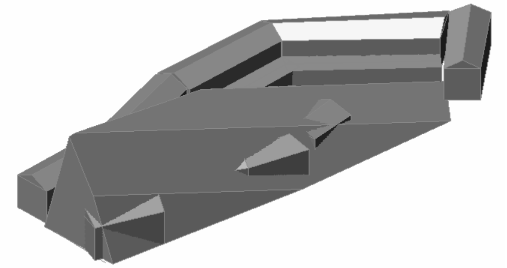

Figure 11: Nucleus No.3, Iso-metric view from the southwest; example of solar envelope on 21st of June between 3 p.m. and 6 p.m.

open toward southwest. The forms of nuclea around the courts are designed as aerodynamic wedges against the northeast winter wind. The courts strictly open toward southwest, from where the summer wind Morjak blows. Due to the capturing of wind the mutual shading of buildings is not possible. The shading of residential buildings is thus provided locally, with pergolas.

4. CONCLUSIONS

In urban planning one of the most important starting points is consideration of the sun path. The sun is important because of the living environment quality, because of the daylighing and heat gains that can reduce the consumption of other energy sources. We can find a great number of examples of respecting this issue on the level of building and on the level of urban planning in historical or vernacilar building. In Slovenia the most efficient examples of bioclimatical design are built in Karst.

Karst is the southwest region of Slovenia, famous for its exceptionally organized settlements. The sub-Mediterranean climate results in warm summers and cool winters with strong northern and northeastern winds. The architecture of Karst responds to these conditions on the level of the building and on the level of the site disposition.

In Karst there appear two basic space dispositions of settlements: linear terraces and buildings surrounding a court. We analyzed the settlement Kobjeglava, which belongs to the second type. The method used for the investigation was the solar envelope method. The solar envelope limits the development within the imaginary volume, which results from the sun's incidence angles. The method enables us to determine the maximum possible bulk that can be built on a certain site (location). Buildings designed within the envelope will not overshadow the neighboring buildings or land.

The Kobjeglava settlement is positioned on the plain, with no limitations regarding site morphology. The organization of buildings around the courtyard is mainly the result of the winds and the security. The residential part is oriented toward south. In front of it an open court is positioned in order to assure the satisfactory duration of insolation during heating season and space for communications. Toward southwest all courts strictly open to the Morjak wind (summer breeze blowing from the sea), which provides summer cooling (Fig. 12). We can see

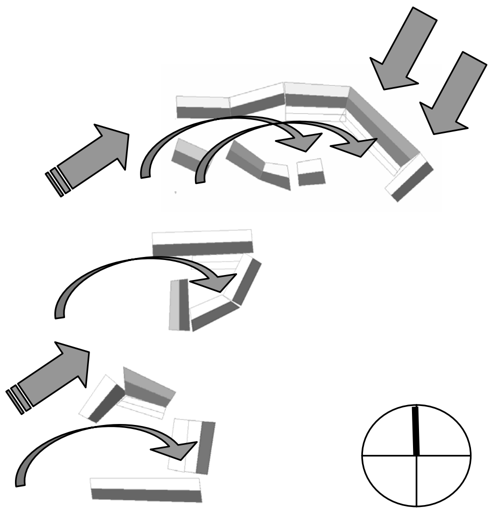

Figure 12: The dispositions of buildings arround the courts in Kobjeglava. The strong winter wind demands closure and protection. The summer wind is led into the court where it cools the buildings.

can see that in all the cases the topographical and the climatic conditions are strictly respected. Architecture and urban planning are closely inter-connected and assist each other in achieving optimum solutions in given circumstances.

The simulations were carried out with the newly developed computer tool. The tool enabled us to analyze vernacular dispositions, which are based on centuries of experience. With their help we established the principles of urban planning, architectural design and composition of building envelope. This experience is a valuable guidance for preparing models of future development in the region.

The investigation showed that the tool offered good support in the analysis of state of art situations and reconstruction of old dispositions and can be used for designing new development.

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