Lepenski Vir - the prehistoric energy efficient architecture

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The prehistoric settlement of Lepenski Vir, which was discovered during the 1960s in Djerdap Gorge on the Serbian side of the Danube River, is well-known for its unusual architecture and preserved house floors. If we analyze this architecture in view of the set of natural (meteorological, geographical, astronomical and vegetal) environmental properties and consider energy consumption for heating and air-conditioning needs for such dwellings, i.e. achieving thermal comfort in those houses, we can conclude that the builders paid particular attention to energy efficiency in building stock while designing those houses. Remains of the architecture of the prehistoric settlement of Lepenski Vir, where operations for energy efficiency improvements are visible and recognizable, are the remains of an energy effective architecture. Their houses were energy efficient considering their age, technology and given location, contributing to the long life of the settlement.

Keywords: Lepenski Vir, energy efficiency, bioclimatic architecture, heat loads, solar energy, compactness.

Introduction

The harmony of architectural style and natural environment has been taken into account since ancient times. In his presentation in Belgrade from two years ago, German engineer Helmut Krames asked the following question: "Did prehistoric people care about energy efficiency?" At this moment, we have to notice that people in the past were much better versed in the nature and its whims than we are nowadays.

Bioclimatic architecture is a new discipline in architecture, which nevertheless has a long tradition, and which relates to such issues. It should give an answer for questions with place of urban planning and structure designing in connection with elements of climate. The questions as follows:

1. Which is the optimum location and orientation for a building (if any choice is possible)?
2. Which are favourable and unfavourable climatic elements; how can they be adapted to the building in an optimum manner and vice versa?
3. How is it possible to improve the microclimate around and inside the building?

Those questions are in the book about bioclimatic architecture, written by Serbian architect Mila Pucar.

An architect needs to make sure that his or her design provides an answer to these issues by adapting the house to the climatic elements (like outside temperature, solar radiation, velocity and direction of wind, etc.) and surrounding vegetation (vegetation has a considerable impact on microclimate). Such a project results in comfortable indoor conditions and saving of energy from fossil fuels needed to achieve such conditions. The project needs to include implementation of RES (renewable energy sources). Solar energy could be RES applied in prehistory.

The basic information about archeological site Lepenski Vir

Lepenski Vir was discovered in the 1960s. The site is well known by its sculptures, architecture and graves. Lepenski Vir is settled on the right, Serbian side of the Danube River in Djerdap Gorge, 15 km upstream from Donji Milanovac and about 160 km downstream from Belgrade.

The person deserving most merit for its discovery was Dragoslav Srejović, archeologist, whose book *Lepenski Vir – a new prehistoric culture in the Danube region,* published in 1969 by SKZ, is the main source of information on this culture. The site is estimated to be about 8,000 years old. Due to construction of HEP Djerdap 1 the original site was sunken, the level of the Danube grew by about 12 m, while the current site was moved by some 150 m, but the original position was maintained.

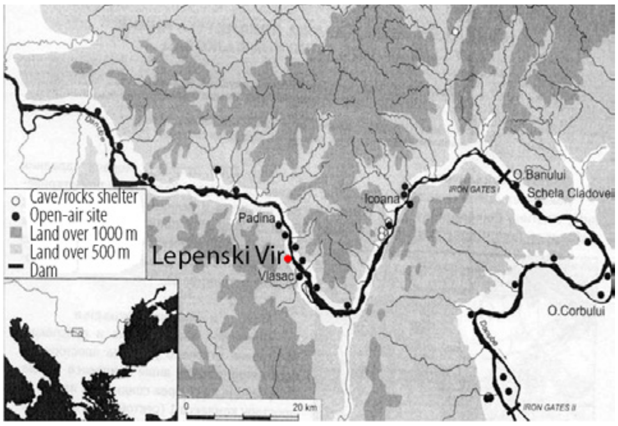

Figure 1. Places of Lepenski Vir culture. [3]
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The recent bloom of solar architecture took place after the excavations, in mid-1970s, following the beginning of the energy crises and so-called "petrol shock". This is why the passive solar heating aspect was not taken into consideration during the excavations in Lepenski Vir.

Nowadays, Lepenski Vir is a museum. The site was displaced due to sinking. The museum preserves the site from devastation due to climatic effects.

Only bases of the houses, made from a hardened material resembling concrete, are preserved; hearths were incorporated in the bases at the entrance, as an active heating system. The third dimension was constructed from perishable materials (like wood, leather, mud…)

Figure 3. Photo of the base. [1]
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and is not preserved. We can only assume what those houses looked like. The architecture is characterized by houses with the base shaped like a truncated section of a circle, with the convex side turned to the river, i.e. sunrise. This shape may also be called a convex trapeze (see **Figure 2**).

The back side is significantly smaller, while the front side is shaped as a circular arch. Lateral sides are inclined. The hearth made of stone blocks in the bank-hinterland direction was placed at the entrance of the house (see **Figure 3**). At the first look we can see that

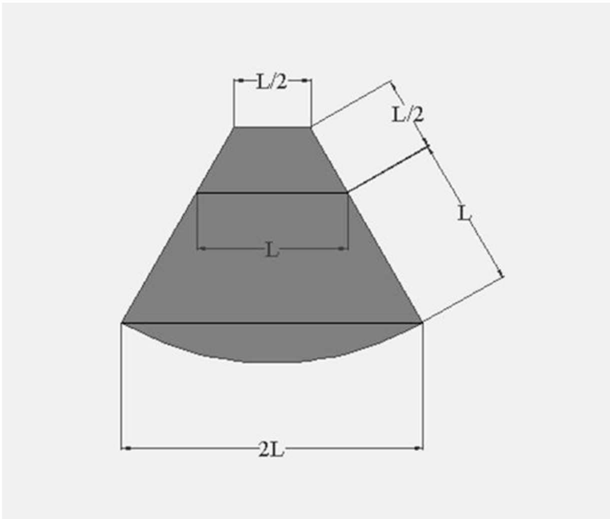

Figure 2. The shape of the base by Dragoslav Srejović. [19] *Please check this image in better resolution on the REHVA Journal digital version.*

hearth at the entrance was placed from the same reason why we install radiator under the window today.

Many, including Srejović himself, wondered: How did this house look in space? Almost nobody asked: What was the point of such construction and why were these houses built in this manner? The answer to the second question may be found even without an accurate answer to the first one. The purpose is obvious: to achieve pleasant living conditions within natural surroundings. The reconstruction of the house was given also by Pedja Ristić, Hristivoje Pavlović, Dušan Borić and others.

Visible energy efficiency principles in the architecture of Lepenski Vir

Winter time – reduction of conduction and ventilation heat loads

What principles were applied in the architecture of Lepenski Vir for reduction of conduction heat loads?

The first principle for reduction of conduction heat loads is compactness. A/V ratio is important as a measure of compactness. If a building envelope is compact, A is smaller and conduction heat loads are smaller. The best figure in that case is the ball.

At Lepenski Vir we know only the floors, so we should consider the perimeter and surface ratio, and then make an analogy to the third dimension. The best figure in two dimensions is a circle.

If we observe shape comparison figures in **Table 1**, we can see that the cylinder with optimized floor at Lepenski Vir is somewhere in the middle. The shape of many houses and buildings have today much less favourable A/V ratio than a cube.

Table 1. Shape comparison.

Figure	A/V for V=1	%	%, If we calculate orientation
Ball	4.84	80.6	80.6
Cylinder	5.54	92.26	92.26
Cylinder – optimized Lepenski Vir floor – south orientation	5.68	94.68	93.94
Cylinder – optimized Lepenski Vir floor – east orientation	5.68	94.68	94.68
Hemisphere	5.76	95.96	95.96
Cube	6	100	100

Floors at Lepenski Vir were very compact. The floor is a combination of a trapeze and circular section. The perimeter of this or similar figure is smaller than of a square. Heat transfer and losses are smaller with this shape. If we compare a cylinder with optimized basis of Lepenski Vir floor with a cube, it saves 5–7% energy in conduction heat loads (if we calculate orientation too). This shape at Lepenski Vir has a good quality in passive solar architecture.

The second principle for reduction of conduction heat loads applied at Lepenski Vir is orientation. Advantages of this asymmetrical or eccentric shape are manifested if adequate orientation is applied. Orientation at Lepenski Vir is mostly to the east and to the river. Southward orientation at the given site was not favourable. Due to ground configuration and hills in hinterland, the construction site was mostly exposed to solar radiation in the morning; the site was facing the river.

The third principle for reduction of conduction heat loads is usage of solar energy for better thermal insulation. Materials applied for construction of the envelope were from the natural local setting. Materials applied for "walls" were mostly wood, leather, mud… All these materials lose their thermal insulation properties under the impact of moisture. Precipitation in Djerdap is by 20% larger than in adjacent areas. Drying of inclined walls in the sun improves thermal characteristic and increases insulation rate. Thus, conduction losses are diminished.

Conduction losses were reduced by compact envelope, drying of walls and improvement of thermal insulation properties of materials used for walls by application of solar radiation, which is why favourable orientation was used.

For reduction of ventilation heat loads, two principles work together: aerodynamic shape and proper orientation. It may be assumed that the settlement was exposed to winds blowing from the river, as the vegetation and steep hinterland reduce the possibility of wind blowing from other directions. The shape of the base is also very favourable from the perspective of loses in ventilation, as it allows for natural circulation with small drops and differences in pressure, enabling maintenance of favourable indoor temperature. The aerodynamic shape of the base, which is much better than, e.g., a square, i.e. cube, is exceptional.

Aerodynamic shapes reduce infiltration of external air into the structure interior. Thus, movement of air indoors is minimized, and heat exchange with surroundings is reduced. The disposition of air vents (windows) is not familiar, which is why calculation of heat losses is pointless. Ventilation losses, which were pronounced, were reduced by using the base of the favourable aerodynamic shape with proper orientation. Wind gusts were reduced by front arc side.

The third principle for reduction of ventilation heat loads is digging walls with earth. It is known that soil has better thermal properties than ambient air. Digging is also implemented for the purpose of protection from wind. The back side of the house was dug due to ground configuration and for protection from wind. The height of digging was between 80 cm and 1 m. In some places, such structure also acted as the retaining wall. The settlement was terraced. Ventilation losses were minimized by the favourable aerodynamic shape, orientation, and digging.

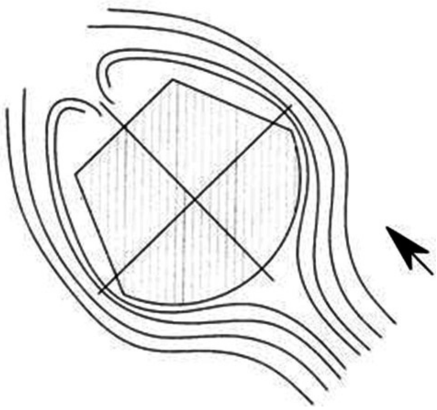

Figure 4. Circulation – the aerodynamic shape of optimized floor at Lepenski Vir.

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Summer needs for cooling

Such architecture may also provide comfortable living conditions in summer. Microclimatic benefits are utilized by the choice of site. Steep hinterland on the west casts shadow on the settlement in the afternoon. This reduced summer heat gains. Thermal load is the largest in the afternoon because of joint action of high outside temperature and solar radiation.

Selection of the location, with all its microclimatic benefits, was very important (in Djerdap, in July it is by 2–3°C colder, while in January it is by about 1°C warmer than in adjacent regions). The need for cooling in summer was reduced by the choice of a favourable location and orientation and utilization of vegetal surroundings. Additional cooling was achieved with simple technic – splashing walls and a floor with river water to evaporate and lowers the temperature.

Figure 5. The terraced settlement and digging.

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The choice of the location, steep hinterland, orientation and vegetal surroundings also enable pleasant living conditions in summer.

Some others secondary energy efficiency principles

In Lepenski Vir, minimization of conduction and ventilation losses in winter and reduction of heat load in summer were achieved using the same beneficial orientation: this **beneficial orientation was towards the east and the river**, resulting from ground configuration.

Energy "production" (heat and light gains from solar radiation) and energy demand (walls mostly need to be dried in the morning after dew) are well-aligned, which is reflected in the choice of orientation. Morning temperatures are lower than outside temperatures in daytime, which is why the need for heating is the greatest in the morning. Outside daily temperatures are the lowest before sunrise. This alignment is mostly due to the predominantly eastward orientation of houses, towards the river.

Figure 6. Side view of steep hinterland.

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The Padina-Gospodjin Vir site

Excavations were also performed at the Padina-Gospodjin Vir site, overshadowed by the discovery at Lepenski Vir. Padina-Gospodjin Vir is also a sunken archaeological site, located some 6 km upstream from Lepenski Vir. It was located on the western, Serbian side of Djerdap; the natural conditions were quite similar to those at Lepenski Vir. The found remains of architecture are very similar to the architecture of Lepenski Vir, but also differ from it in some details.

Excavations were performed by academician Borislav Jovanović before the site was sunk. The architecture of the Lepenski Vir culture did not emerge haphazardly, as similar house remains were found both in Lepenski Vir and in Padina-Gospodjin Vir, sunk archaeological site in the vicinity, with similar microclimatic conditions.

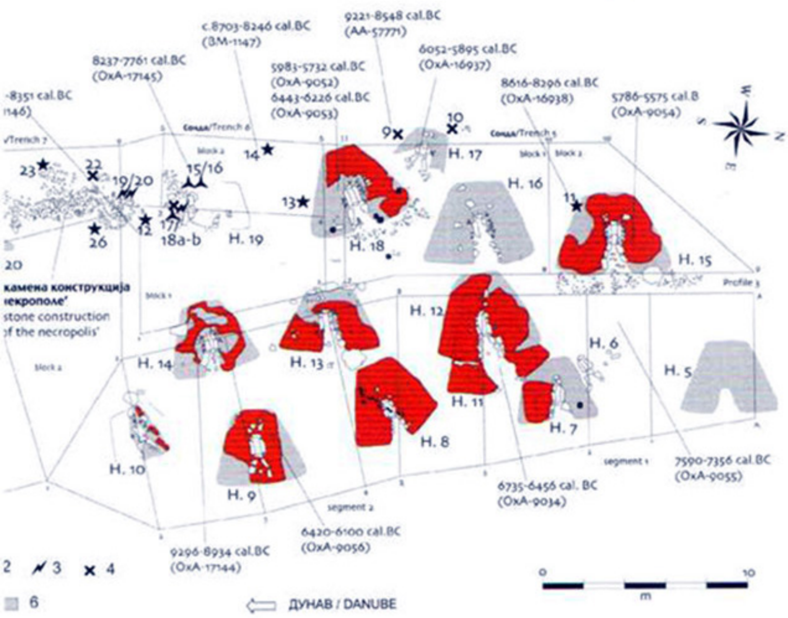

Figure 7. The layout of the base of Padina-Gospodjin Vir settlement. [5]

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Conclusion

We may speak about the primal passive solar and bioclimatic architecture. The shape of houses is very compact and contributes to saving of heating or cooling energy. The remains of the architecture of Lepenski Vir are silent witnesses of measures applied to improve energy efficiency. The houses in Lepenski Vir and Padina-Gospodjin Vir are examples of energy efficient construction of the time, location and given the condition of technology and applied materials. The architecture of Lepenski Vir did not emerge haphazardly, as similar house remains were also found at the Padina-Gospodjin Vir site.

The inhabitants of Lepenski Vir and Padina-Gospodjin Vir were aware of some principles of bioclimatic architecture. This is proved by the remains of architecture (house floors) and natural surroundings of the site, including movement of the Sun along the firmament. This is also proved by the fact that in this settlement and at that site people were living for about 2,000 years, or about 80 generations* (let us remember the definition of sustainable development!).

The answer to the question of Helmut Krames, engineer, from the beginning of the paper, whether people in prehistory cared about EE in building stock is: the remains of the architecture of Lepenski Vir (including the Padina-Gospodjin Vir site), which emerged some 8,000 years ago, indicate to recognizable measures aimed at increasing EE in building stock, which were implemented in the design and construction of houses and settlements at those sites. Even though there is no written evidence, bases of the houses speak about the applied measures the sense of which may be grasped only when observed within the natural (geographic, meteorological, vegetal, and astronomic) surroundings. The role of the Sun and solar radiation on the sites is very important to understand the purpose of the architecture of Lepenski Vir. Even though we may not be certain of what those houses looked like, we may positively conclude, based on the remains of the architecture, that the purpose of such construction was to ensure comfortable conditions in them, taking into consideration energy efficiency in buildings. Even though the third dimension of the house is not known, it must have followed the shape of the preserved base. **The remains of architecture in Lepenski Vir are the remains of an energy efficient architecture and ecological houses.** ■

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* The data from this paper relating to the 2,000 years, or about 80 generations of duration of the settlement, needs to be taken only as a rough illustration of the long life of the settlement.