Nenad Miloradović, dipl. ing. mech.
„Beogradske elektrane“, Belgrade
nesoni2@nadlanu.com
Prof. Dr Nenad Tasić, PhD, archaeology
Faculty of Philosophy, University of Belgrade
ntasic@gmail.com

Neolithic Settlement Vinča – thermal aspect

Introduction

The archaeological site *Belo Brdo* in Vinča is located at the right bank of the river Danube, 14 km downstream from Belgrade. Systematic excavation of the archaeological site has been conducted since 1908, and for the first time it was started by an archaeologist Miloje Vasić. The remains of the settlement in Vinča lie in cultural stratum which is 10.5 m high and are related to the period of the late Neolithic (the period from 5 200 BC to 4 200 BC [13]). The oldest settlements lie at 10.5 m from the surface and represent round shaped dugouts or dugouts with ellipsoidal foundations dug in loess and have tent like roof made of brushwood, reed and straw. Above those tents like settlements a settlement of a new type was built. The preserved foundations are quadrangular and oriented in direction South East – North West, while the walls were vertical.

As a part of an interdisciplinary project *Archaeological research in Vinča*, a research which deals with the study of prehistorical architecture in a different way is conducted. In order to establish consumption of energy sources for heating of the houses and the degree of comfort in the Neolithic settlement Vinča, it was necessary to analyse thermal behaviour of buildings used at that time for living.

Firstly it should be noted that it is difficult to precisely calculate the consumption of energy sources, because the methodology used today for that purpose is based on the consumption of modern building materials and solutions. In addition to that, the calculation of thermal losses of houses presents the total amount of transmittance losses (heat exchange through the walls) and ventilation losses (heating of cold air which got into the room). In case of the Neolithic houses, the calculation of ventilation losses is very unrewarding, because at that time there were no window constructions as we know

them today, and the infiltration of external air into the room was significant. Therefore every result of calculation of thermal losses, based on the modern methods, can be debatable and there is no point in analysing those calculations into details. On the other hand, the significance that this research has for the interpretation of archaeological remains is indisputable. On the bases of that calculation, the influence of human activity that lived in Vinča for thousand years on the environment can be established as well as the amount of wood that must have been consumed with the natural forest renewal and the influence of that on the Neolithic landscape.

Nevertheless, in the following text it will be shown that the specific construction of the Neolithic houses in Vinča is of great importance for understanding of how modern low-energy buildings function and that the technical building solutions used in the Neolithic period can make contribution to energy saving in the future.

Thermal characteristics of building materials in the Neolithic

For the materials used for building houses in the Neolithic settlement Vinča it can be said that they have favourable thermal-insulation characteristics because of the ingredients of those materials. Wall material in houses consists of the mixture of mud, sand and filling materials. Materials used in the Neolithic for building houses in the Neolithic settlement Vinča can be treated as a mixture of earth, send and scraping (since it can be concluded that filling materials has similar characteristics to scraping), which depending on this ratio in the mixture, gives the maximum value for λ which is 0,52 W/мK (for dry material). This has better thermal-insulation characteristics than brick. **Unfavourable mechanical strength of the mixture of mud, sand and filling materials is substituted by using wood for the bearing construction**. A firm skeleton of the construction was created in this way, and walls made of mud had favourable thermal-insulation characteristics and they provided pleasant comfort in rooms.

These are data for some interesting materials that can be found in reliable references:

Table 1 – Coefficients of heat conduction for building materials used in the Neolithic

material	heat concusction coefficient λ [W/мK]
ground, earth [1]	0,52
sand, dry [1]	0,33
clay [3]	0,7-0,9
wood [2]	
spruce, pine tree	0,14
oak tree	0,21
scraping [2]	0,09
solidbrick [2]	0,47-0.76

The Quality of Insulation and Transmittance Losses

The necessary amount of heat for heating of one Q is calculated as the total sum of so called transmittance Q_T and ventilation Q_V amount of heat [2].

$$Q = Q_T + Q_V \tag{1}$$

The following is an illustration of insulation quality in the Neolithic settlement Vinča. We can assume that the thickness of exterior walls is 25 cm (which is close to the wall thickness at the archaeological site). The heat conduction coefficient for that kind of wall made of mixture of mud, sand and filling materials (the assumed heat conduction coefficient λ = 0,52 W/mK) is

$$k = \frac{1}{\frac{1}{\alpha_U} + \frac{\delta}{\lambda} + \frac{1}{\alpha_S}} = \frac{1}{\frac{1}{8} + \frac{0.25}{0.52} + \frac{1}{25}} = 1.55 W/m^2K \tag{2}$$

In comparison with the heat coduction coefficient for an exterior wall made of brick (ρ=1800 kg/m^3), of the same thickness (25 cm), which is 1,97 W/m^{2}K, [2]), **the thermal insulation of a wall is better in the Neolithic for approximately 20%.** This refers to dry material, and it should be noted that by increasing of dumpness significantly worsens thermal-insulation charcterstics of that kind of material.

Apart from thermal-insulation characteristics, these walls have significant ability of heat storing, that is to say the ability to hold heat for a while after the furnance is put out. The heat storing ability depends on the size of the wall and the bigger the wall is the greater the ability is. This influences positively on the comfort of the room.

About Ventilation Losses

Houses in the Neolithic settlement Vinča had significant ventilation losses. We do not know the size and position of windows in houses, glass did not exist at that time, and probably there were leather or straw covers on the windows. The ventilation losses in the Neolithic houses can not be calculated. The only thing we can do is to conclude that they were significant. Those ventilation losses depend on the speed and direction of wind and **for that reason the houses in this archaeological site were closely built with small spacing between them. Since the ventilation losses influenced the comfort in rooms most, people in Vinča planned the whole settlement in a way that could reduce gusts of winds.** It should be noted that the houses were not positioned in sequence which would be even more efficient, but only closely built.

Picture 1 – 3D animation of reconstruction of a Neolithic house in Vinča [4])

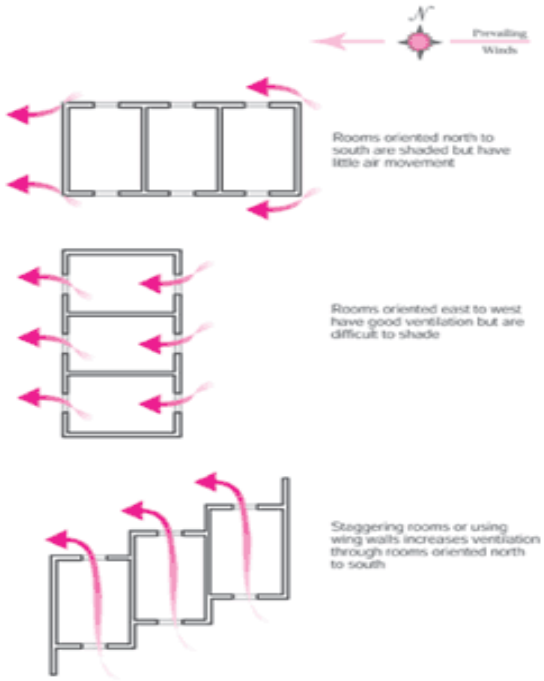
Modern houses have ratio of transmittance and ventilation losses approximately 70%: 30%. **For houses in the Neolithic this ratio was much more in favour of ventilation losses**. Share of ventilation losses of heat in heating reduced the comfort in rooms. Benefits in comfort gained by using favourable materials for thermal-insulation and reducing transmittance losses were annulled by lack of efficient windows.

"In winter, regardless of measured temperature, wind reduces the temperature of the settlement and increases heat losses. The settlement itself has influence on wind by reducing its speed and changing its direction" [6]. When the wind blows around the house, there is pressure surge from the frontal (attacked) side. "On lateral sides there are number of whirlpools, while on the back side there is an area with depression and distinct whirlpools" [7]. Also, "cold external air comes into the house only through the frontal attacked side, while it leaves as heated internal air through other sides" [8]. If the wind is stronger, the value of pressure surge is higher on the attacked side, and the amount of the cold air coming into the house is greater as well as heat losses. Values of pressure surge depend on aerodynamic characteristics of the house and the size of spacing. In that way natural ventilation of the house is accomplished. Since there were only single-story buildings uplift pressure can be disregarded.

"Regarding direction of winds, the longer side of the house should follow the direction of the most common winter wind in the environment where the house is located" [10]. By minimizing the frontal side which faces the river, not the sides facing hinterland or woods, the surface attacked by wind and ventilation losses are reduced. Orientation of a rectangular house, whose smaller side is exposed to the gusts of winds, has worse natural ventilation than a house with an orientation rotated for 90 degrees (as illustration see picture 2, taken from on line references [9]; in this case it should be noted that for the natural ventilation the position of the windows is very important). In such a house movement of air is minimal. If we consider winter period, it means that such house is more comfortable for living because the natural ventilation is reduced. Also, closeness of neighbouring houses and trees reduces the wind speed and ventilation losses. When the wind reaches the house it becomes weaker and uses its strength and thus it changes its circulation pattern. "Natural or artificial protection of the settlement from winds creates favourable micro climatic conditions and realistic possibilities for reduced consumption of energy for heating of the house" [11].

Passive protection from winds was created in Vinča, most probably in two ways: by choosing the type of settlement and by orientation of smaller sides of houses towards the river. The Neolithic settlement has characteristics which reduce ventilation losses: space between the houses is relatively small, so the whole settlement is closely built and

smaller sides of house face the cold winds which come from the direction of the river. “On of the ways of protection from winds is close building… Neighbouring houses, vegetation, etc. reduce thermal losses of a house and protect it from winds. The space naturally protected from cold winds (in most cases these are north winds with the exception of south-east wind Košava) provides great advantages” [11].

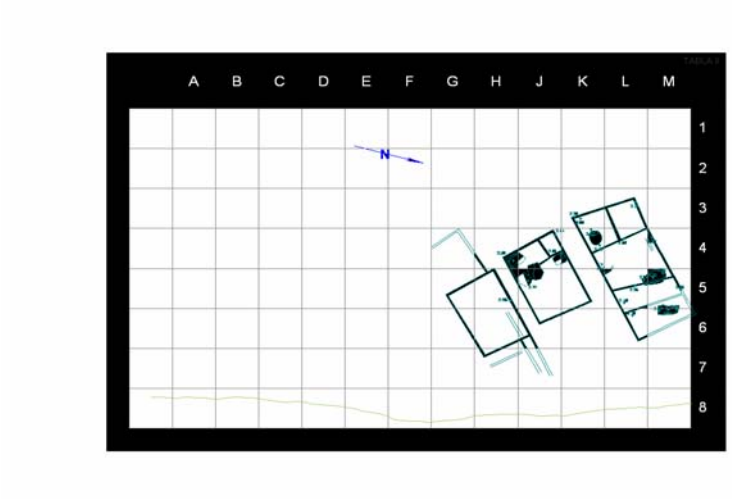


Picture 2 – Building orientation and natural ventilation [9].

In the following picture (Picture 3) the position of the Neolithic settlement in Vinča is shown with small spaces between the houses. It can be concluded that the attention was paid to the orientation of the houses while they were built. The longer axis of the houses was oriented towards northeast – southwest direction and the narrow sides of the houses were facing the river.

The position of the river Danube has the greatest influence on the local wind patterns and it can be said that the orientation of houses in the settlement was conditioned by openness towards the river. The nearest weather station is in the Institute “Vinča”, but it measures wind for aero pollution at 40 m away from the ground, where south-east winds, such as Košava dominate. For more precise conclusions it is necessary to measure the intensity and direction of winds at the archaeological site. It must be noted that we will never know the characteristics of wind patterns in the Neolithic. The seasonal

(winter) wind pattern is important, as well as the temperature of wind patterns (wind patterns in relation to external temperature).



Picture 3 – Orientation of houses in Vinča (relevant reference [4]).

Floor Characteristics

The floor was double-layered: the lower layer was made of wooden semicircle forms, and on top of that loam was placed. Thus, **there was insulation layer made of wood**, which is a very good way of holding room temperature. Below these layers there was a layer of ceramic scrap, which was most probably used for filling uneven surfaces. Wood and clay were used as building materials; however the building procedure involves levelling, stabilization of the foundation and damp proofing.

As illustration we can assume that the floor consisted of 7 cm thick layer of ceramic scrap, 8 cm thick layer of wood and 10 cm thick loam covering. In that case, the heat conduction coefficient from the inside of the room to the ground was as follows:

$$k = \frac{1}{\frac{1}{6} + \frac{0.07}{0.55} + \frac{0.08}{0.21} + \frac{0.1}{0.8}} = 1.25 W / m^2 K \qquad (3)$$

In comparison with concrete slab used for floor on the ground (the heat conduction coefficient 1, 34 W/m^2K; see [2]), we get slightly better value.

Conclusion

In the Neolithic settlement Vinča, houses were built of materials with favourable thermo insulation characteristics. This fact influenced on transmittance losses of heat for heating to be relatively small in comparison with ventilation losses of heat. Performed calculation shows that when compared with modern walls made of solid bricks, **thermal insulation ability of walls in the Neolithic is better for about 20%.** Transmittance losses of heat are smaller in comparison with modern building (with the exception of buildings with the increased insulation). Due to the fact that the **ventilation losses were dominant** for comfort in rooms, the houses in the Neolithic settlement were closely built, with the purpose of reducing ventilation losses of heat caused by gust of winds and minimization of natural ventilation in winter. **It is most probable that the passive protection from wind was created in two ways: by choosing the right type of settlement and by orienting narrow sides of houses towards the river.** At that time houses were not lined one after the other, in order to be more efficient about heat losses, but the spacing between the houses was relatively small. Orientation of houses is not in accordance with the wind patterns according to data acquired from the contemporary weather stations; however, there is a significant possibility that the micro climatic characteristics of the area where the Neolithic houses were located greatly influenced wind patterns. Natural and ecological materials were used for building houses.

The houses in the Neolithic settlement Vinča deserve attention because of their bioclimatic architecture, because of understanding of building principles of low energy buildings and because of saving of energy for the purpose of heating. **If the Neolithic house could be improved by using modern window constructions and other wooden constructions in a house in order to reduce ventilation losses of heat, it would definitely be highly ranked among modern low energy buildings.** The influence of

wind on heating of modern buildings is not as significant as it used to be in the Neolithic; however, most probably an interesting passive way of protection from wind was created.

The construction of floors is instructive. It did not only have thermal insulation layer made of wood, it also had a hydro insulation function because of the loam layer.

It should be noted that the **calculation results in this paper should be considered only as approximate values**, which were given with the purpose of better illustration of the text.

BIBLIOGRAPHY

[1] Мирсад Ђублић, *Биогас*, Техничка књига, Београд, 1986, 108.

[2] Бранислав Тодоровић, *Пројектовање постројења за централно грејање*, X издање, Машински факултет, Београд, 2005, 89-95, 219-221.

[3] Ђ. Козић, Б. Васиљевић, В. Бекавац, *Приручник за термодинамику и простирање топлоте*, Грађевинска књига, Београд, 1983, 121, 196.

[4] Архива археолошких ископавања у Винчи, Катедра за археологију Филозофског факултета Универзитета у Београду.

[5] Мирјана Лукић, *Соларна архитектура,* Научна књига, Београд, 1994.

[6] Мила Пуцар, *Биоклиматска архитектура*, Посебна издања ИАУС бр. 45, Београд, 2006, 37.

[7] Радисав Милорадовић, *Аеродинамика малих брзина*, Ваздухопловни Савез Југославије, Београд, 1962, 12.

[8] *Правила прорачуна топлоте потребне за грејање зграда*, посебно издање часописа КГХ, СМЕИТС, Београд, 1985, 9.

[9]http://www.austinenergy.com/Energy%20Efficiency/Programs/Green%20Building/Sourcebook/passiveSolarDesign.htm

[10] http://www.un-ecobuilding.info/download/koncepti/pasivna_arhitektura.pdf

[11] Мила Пуцар, Милан Пајевић, Милица Јовановић-Поповић, *Биоклиматско планирање и пројектовање – урбанистички параметри,* Завет, Београд, 1994, 44,71-73.

[12] Рекнагел-Шпренгер, *Грејање и климатизација,* приручник, II измењено и допуњено издање, обрада за Југославију, ИРО Грађевинска књига, Београд, 1984, 763.
[13] Ненад Н. Тасић, *Vinča – The Third Glance (Excavations 1998–2002).* Prehistoric Archaeology and Anthropological Theory and Education, Reports of Prehistoric Research Projects 6–7. Lolita Nikolova, J. Fritz, and J. Higgins, eds. Pp. 1–8. Salt Lake City: Karlovo, 2005.

Key words:

Neolithic settlement Vinča
Transmittance losses
Ventilation losses

Summary:

In the Neolithic settlement Vinča houses were built of materials with favourable thermo-physical characteristics, thus transmittance losses of heat for heating were relatively small in comparison with ventilation losses. Approximate calculation shows that the Neolithic thermal insulation ability of walls is 20% better compared to the modern brick wall. Because the ventilation losses were dominant, most probably passive wind protection was created in two ways: by choosing a closely built settlement and by orienting smaller sides of houses towards the river. Natural and ecological materials were used for building houses, and the specific floor construction is instructive and creates thermal insulation because of its wooden layer. In order to reduce energy consumption in some houses with several rooms there were two furnaces, so the rooms could be heated separately, depending on the needs. If the Neolithic house were improved by modern window and door constructions for reducing ventilation losses of heat, it would definitely be highly ranked among low energy buildings.