PASSIVE ARCHITECTURE AND APPLICATION OF WOOD IN CONSTRUCTION OF PASSIVE HOUSES

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ABSTRACT:

This paper deals with the topic of construction of passive houses. The concept of passive architecture is theoretically described, as well as basic features and advantages of passive houses and application of wood and wooden materials in construction of passive houses. Statistical indicators of application and construction of passive houses in Bosnia and Herzegovina are given in addition. Practical examples of passive houses and wooden components that are applied in the very construction of passive houses are introduced and some of the advantages of application of wood as a material in passive architecture are stated too.

1. INTRODUCTION

Passive architecture is a term that is lately often used in architecture and construction and refers to buildings that are constructed so that they on their own look like a sun collector and heat tanks in the same time. Such way of usage of solar energy is very efficient and cheap because no additional equipment for collection and usage of energy is needed whatsoever. Passive architecture is characterized by functional design and not by usage of some special contemporary technology and that is why, in principle, such a house does not have to be more expensive than a classic house. By passive manner of house construction it is possible to decrease the necessity of other energy – generating products for the needs of heating up to nearly 90 %.
The first passive house was built in Darmstadt, Germany in 1990. It is estimated that the number of passive houses in Europe until the present day goes from 25.000 – 30.000, with the largest percentage in Germany, Austria, Switzerland and Scandinavia. In Bosnia and Herzegovina passive houses still do not have almost any function. Reasons for this may be in conservative approach of the local population and the belief that classic construction is the best and the most efficient. In Bosnia and Herzegovina there is a large number of companies that deal with construction of wooden and low – energy houses that practice promotion of passive construction, which, to some extent, gave results since there is a plan to build the first complex of passive houses this year in Sarajevo, Bosnia and Herzegovina.

2. FEATURES OF A PASSIVE HOUSE

The basic feature of a house that has characteristics of a passive house is that by a square meter of residential area you do not spend more than 1.5 liters of fuel oil or 1.5m³ of gas.
In a passive house with no active heating system or air – conditioning you can acquire a pleasant room temperature both in winter and in summer season. Passive construction offers enhanced residential comfort where the needs for heat energy do not go over 15 kWh/m². Realization of a passive house sets high requirements on the quality of applied construction components. All outer

elements of a house or a building, except from glass surfaces, should be heat isolated so well that the heat transfer coefficient is not higher than 0.15 W/(m^{2}K).
The price of a passive house depending on construction can be slightly higher than classic construction, it can possibly be lower, but by all hitherto indices usually a price of one passive house is 20 – 25 % higher than the price of a classic house. However, if we take into consideration the savings in energy by all indices such a way of construction pays off over 10 years.
When we add wood as a base for construction of such a house to its features of agreeable life (pleasant constant temperature, minimal waste of energy – generating products, ecologically acceptable statistics, high construction standards and so on) we get nearly perfect harmony and ambience very convenient for living.

3. HEAT ORIENTATION AND ACCUMULATION

The basic principle of passive architecture is proper orientation with respect to cardinal points and opening of the object towards the Sun and usage of its energy. Large window surfaces on the south side must not be shadowed so that passive solar gain can be optimal and that windows contribute to heat stability of the house. The least bend with respect to south enables the greatest usage of winter solar radiation to the windows and in summer it prevents overheating of the rooms caused by insolation from the west side in afternoon hours. Highly effective heat recovery in ventilation system with exploitation higher than 75 % is achieved at low energy consumption.
If we want to use the Sun potential to the fullest we have to enable it to penetrate into the interior of the building in a maximum amount. This is achieved in such a way that most of the windows and glass surfaces are set at south. Though, glass surfaces must not be too big, since over nights and cloudy days the heat accumulated inside the house is lost exactly through the windows.
In order to decrease the heat loss through glass surfaces isoglass or thermoglass is used. In some cases moving shutters are used, which cover the glass at night in order to decrease heat loss. From east, west or north side smaller windows can be set that serve exclusively to ensure the daylight. Large glass surfaces can cause overheating of rooms in warmer part of the year. In order to impede this we shall use the fact that winter Sun's path is very low, and summer Sun's path is high. The length of the canopy must be accurately calculated so that in the period when the users no longer need canopy heating, it blocks penetration of the Sun through the windows.
Optimal orientation of the object and non – existence of obstacles that would cast a shadow on the object represent further assumptions on how would passive solar energy – light and heat – easily penetrate the interior. If the passive house is built in the construction of floors, that is, two and more floors, the standard of passive house can function without the object being oriented at south. Passive solar buildings mostly have ground plan (view from above) in the shape of rectangle (figure 1), so that one side of the rectangle is longer than the other.

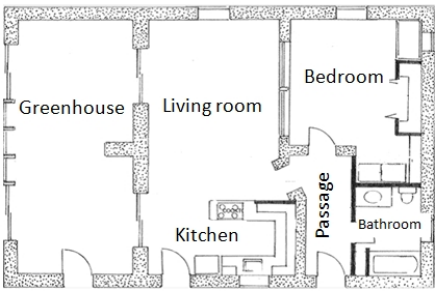

Figure1. Ground plan layout of rooms with respect to north

Figure 2. Winter garden

In order to maximally use the influence of the Sun, the longer side must be turned along the axis east – west, so that the whole longer side of the buidling is exposed to the Sun that comes from south (or north if we are in the south Earth hemisphere).

The system of functioning that is based on good isolaton and usage of all resources suitable for healthy and comfortable way of life make a passive house special and high – quality mode of construction. The basic components of a passive house are: direct grasp of solar radiation, Trombe wall and greenhouse. Direct grasp of solar radiation includes principle of setting the glass surfaces at south side of the house in order to enable transmission of as greater amount of Sun radiation as possible. Trombe wall is turned to the Sun and imagined as passive solar collector. It is usually made of bricks or concrete of darker colours that draw the light more. At the distance of 2 – 10 cm in front of the wall there is glass. In practice two types of Trombe wall are used: without aperture and with apertures at the base and top of the wall. After passing through the glass, Sun radiation falls to the Trombe wall and heats it. The velocity of transmission of the heat from outer to inner side depends on the material of which it is made and its thickness. During the ventilation cycle solar energy is stored in a container while in the cycle of heating the Trombe wall releases the accumulated heat energy.

Greenhouse is at the south side of the house. Behind it there is a massive, dark coloured wall that absorbs Sun radiation. The glass is mainly resistant to longterm Sun radiation, and the heat remains in the room. The greenhouse positioned at the north side that is not insolated must be thermally isolated.

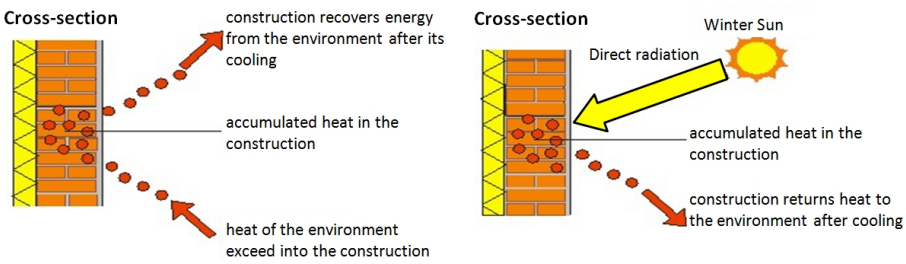

Figure 3. Heat accumulation

Heat accumulation is a feature of construction materials to be able to accept the lead amount of heat, accumulate it inside themselves and at the process of cooling the environment pass it again to the environment. This feature of passive houses is very important during winter period when the heating does not work continually for the whole day, but is, by the rule, stopped during nights. In order to achieve the best possible conditions for heat accumulation in construction elements, it is necessary to set the materials with bigger specific weight in multilayer baffles on the inner, warmer side. This means that heat isolation of margine construction should always be set at the outer side. Concept of the house, its position, isolations and calculations must satisfy high stanards and it is necessary to gain almost hermetically closed space inside the house since, otherwise the precious heat would come out through joints, junctures and various apertures.

4. WOOD FEATURES IMPORTANT FOR PASSIVE ARCHITECTURE

In construction of passive houses it is a frequent case to use wood as a construction material. Massive chucks have the property of keeping constant temperature in the center of the cross section during the whole year. That makes them excellent heat isolators both in winter and in summer. Wall heat transmission coefficient depends on the thickness of the chucks, and goes from 0.09 - 0.03 W/m^2K. An interesting data is that wood merely 3cm thick has heat isolation like 45cm concrete or 18cm brick.

Apart from heat isolation humidity is important as well. Namely, with wooden constructions it shall keep the humidity in the room within satisfying limits by the principle of autoregulation so that no

additional air conditioning devices or humidifiers are necessary. Wooden materials shall absorb moisture when there is toom much of it in the air and release it when the air is dry. That is why the air in a passive house in which wood is applied as construction material shall be neither too dry nor too damp.

In its microstructure wood is made so that it transmits the air in both directions. In this way continuous exchange of inner and outer air is ensured without cooling or warming the interior since, apart from this, wood is an excellent thermoregulator.

Since wood does not have electrostatic features it shall not charge and draw or keep microparticles of dust and pollen and that is why accumulation of dust and allergens is reduced to its minimum. Apart from that, houses in which we use wood are protected from fungi and mold so that inside the house an anti – allergenic environment is created which is especially important with persons who suffer from diverse forms of allergies. One of the biggest prejudices related to passive houses in which we use wooden materials is that they are subject to fire. This prejudice is completely unreal since modern passive houses have guaranteed fire resistence equal to that of classic construction, sometimes even higher. Wood ignites harder than most of other materials we can find in houses. Wood ignites, of course, but very slowly and in a predictable manner. Since wood contains water in itself when the fire starts that water starts to release. Carbon layer appears on the surface of the wood and it conducts heat poorly so it functions as an isolator. Thus, when the wood carbonates at the outer side it impedes intake of oxygen in the interior of the wood and if new energy is not supplied the fire extinguishes. In this way the wood protects itself, and house construction keeps its stability even at high temperatures.

When it comes to earthquakes for wood we can say that, opposite to concrete, it can take compression and tensile forces, so that construction is more elastic than classic construction. This important feature makes it more resistant in the case of earthquake. Tests and experiences from Japan and the USA, countries known for large number of earthquakes, have shown that wooden constructions can endure catastrophic earthquakes with minimal damages.

Wood as construction material requires very small amount of energy during construction of elements. Additionally, wood is the only renewable construction material. If we compare wood with some other materials that are more frequently applied in construction, such as concrete or brick, then we can say with right that wood as a natural material is economically, ecologically and with respect to health the most acceptable when constructing passive houses.

5. APPLICATION OF WOOD IN CONSTRUCTION OF PASSIVE HOUSES

With construction of passive houses various types of constructions can be applied. In this paper we shall focus on the so called easy construction that means usage of wood in outer walls as well as corresponding isolation. The basic advantage of easy construction is that heat isolation is not set on the wall but between the wooden constructions (figure 4) which decreases wall thickness with the same effect of heat isolation.

Figure 4. Wooden construction of outer walls of a passive house

Basic construction of this type of passive house is the system of poles and beams that make the wooden frame. The thickness of poles and beams should not pass 16 [cm] that could not enable suficient heat isolation so the wall construction is drawn up from more layers. From outer side we get an additional layer of heat isolation and from the inner side an installation layer is derived which also represents one sort of heat isolation (Figure 5).

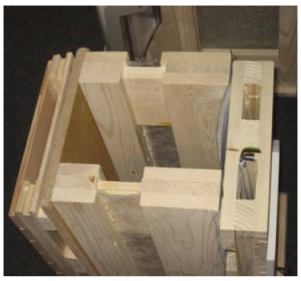

Figure 5. Model of wooden wall construction

Figure 6. Wooden I beam

Ratio of wood in the wall is proportionally high. Since wood has higher heat conductivity than isolation it happens that heat bridges are made in the wall and they attenuate the isolation of the wall, that is, of the house. In order to decrease this fact wooden beams are used (Figure 6) and they are made of top and bottom bar of massive wood, while in between there is a fill of wooden material (tied plate and OSB plate). Smaller cross section of I beam influences the heat transmission of the wall less. Between the I beams there is usually incused heat isolation. Wall has 20 % better heat isolation than rectangular massive poles as well as high static capacity. They are made in the height of 20 to 50 [cm]. Thickness of heat isolation depends on the material and it goes from 25 to 40 [cm], even though it can be bigger. The choice of the material of heat isolation depens on capacity construction of the passive house. With easy construction mostly cellulose and wooden fibers are used, as well as wool or hemp. Heat isolation is set by insufflating between the wooden constructions (figure 7).

Figure 7. Insufflating heat isolation between wooden contructions of passive house.

By insufflation the heat isolation fills the space well so that there are no cracks through which the heat woud go out. Heat isolations differ by price and in ecological component. Since passive houses are ecological by its concept then when chosing the material for the isolation attention must be paid to see whether they are natural, made wiht small consumption of energy and if they are healthy for people and their surrounding. For ensuring the standard of passive house the selection of construction

technology is not the key factor. When projecting and constructiong passive house it is necessary to ensure heat shell at whole cross section of the house (Figure 8).

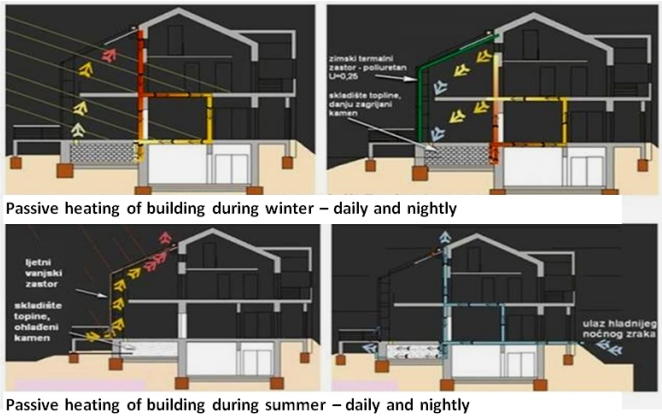

Figure 8: Circular course of heat in winter (up) and summer (down) period

Heat shell of passive house must be completely made without heat bridges and air – resistant, no matter which material is used.

6. CONCLUSION

Passive architecture represents the way of construction in which solar energy is used for gaining and preservation of heat, and all natural materials suitable for comfortable life in such buildings. What makes a passive house so "smart" and represents the base is heat accumulation and isolation, that is, the heating system. The house must be well – isolated in order to decrease energy losses. With good accumulation of heat that the house receives through properly set tubes for heat conduction, and proper isolation around each aperture where thermic bridge will not appear, this house uses every natural material and especially wood that proved to be the optimal material and thus it becomes a trend due to its efficiency and economy. Wood is applied with construction of passive house and represents the so called easy construction since such walls are thinner with the same heat efficiency. The price of construction of passive house is somewhat higher than the classic construction but in a short period it pays off concerning the energy savings. Passive house is on a high level from ecological aspect as well, so that in the future it shall be more applied and it remains a hope that it shall find its wide application as energetically efficient and ecologically acceptable solution in Bosnia and Herzegovina as well.

7. LITERATURE

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