

## PASSIVE HOUSES IN SLOVAK CONDITIONS BUILT OF WOOD AND NATURAL BUILDING MATERIALS



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### Summary

Sustainable development means that any encroachment into the ecosystem must be done in such a manner that the survival of future generations is not threatened in any way. Biologically correct building describes a method of building which respect nature and biological processes. Other terms often used to describe ecologically appropriate building practices include „sustainable design“ or „green building“. Green building means using natural materials to construct a building that places the health and general well-being of the occupants first [1]. The most important criterion would be probably to choose only renewable materials (such as wood, natural insulating materials or unbaked clay) that have not been treated with toxic, health threatening substances.

**Keywords:** natural building material, sustainable construction, biologically correct building, environmental optimalization, life cycle of the building, wood, insulating products, physical properties, energy consumption, Passive House.

### 1 Introduction

Principles of sustainable buildings bring new loads in the sphere of development of building materials. From this point of view new materials and constructions are evolved according to actual environmental criterions. At the same time it is necessary to ensure the same requirements of efficiency, quality, dependability and durability of the structures and structural materials as by using common building technologies. Their use brought new views on the architecture and they affect changes of building technologies. In terms of research in section optimizing of building structures from the environmental point of view possibilities of using wood and insulating products made from renewable raw materials in Slovak conditions are checked. Goal of the research is to optimize the construction layers and elements by ensuring physical properties, deals with the characteristics of environmentally friendly methods. It recommends various constructions using natural materials and describes two examples of Passive Houses built in Slovakia.

## 2 Environmental assessment of materials, constructions and buildings

Building materials during their life cycle influence individual components of the environment as well as human health. Environmental optimization aims to find the most suitable solutions considering the widest scale of the components and effects. One of the most important tasks of environmental assessment is to balance the amount of energy in life cycle of the building. Assessments are applied on single construction layers, construction elements, buildings and its parts. The elaborated data can be used for the comparison of different solutions. The notion of sustainable building and urban development refers to the effect of buildings on the environment in all their phases from the production of building materials to the use of ecologically sound and non-toxic substances in building and finally to the eventual demolition of the buildings.

## 3 Natural building materials

Buildings should not only be energy efficient, but be made to last longer using materials whose manufacture has minimal impact on the environment. Toward this attention must be paid to the use of renewable raw materials. At the production of this components should be used simpler technology, as well as local, recycled, recyclable or compostable materials. There are also not so many problems with environmentally harmful byproducts or waste. Natural building materials without synthetics, such as natural stone, wood, clay, wood fiber, straw, hemp, flax and reeds can be produced without a great deal of energy. Their production and use should not require excessive energy nor create health risks. Water reeds have been used as a roofing material in Slovakia for centuries. Reed as a building material is an easily renewable resource. Reed matting is an excellent means of insulation and a base for clay plasterwork. Flax and hemp are recognized as a valuable raw material for insulation. In some European countries, particularly in Germany, has begun an experimental cultivation. In Slovakia are not yet commercially cultivated, although they are very simple to grow. Straw bale as a construction material is becoming increasingly popular. Clay has always been a traditional natural building material.

### 3.1 Building with wood

Timber is the classic example of regrowable building material. It stores energy and CO<sub>2</sub> and requires very little production (embedded) energy. It is, therefore, the ideal sustainable material. Wood can have the edge on other materials, especially as it is also a renewable material and therefore ecologically sound. At present just a few percentage of the detached houses erected in Slovakia are made of wood. In Slovakia there is still strong prejudice against wood frame buildings, although wood construction saves energy and resources. The exterior wall of a wood construction can be two-third thinner than a typical solid masonry wall with the identical heat loss coefficient, what means that the identical floor area will offer 10% more space for the occupants. The materials for a wooden house are on average 10% cheaper than those for a house built with other materials [1], but in Slovakia may it be not like this. Modern manufacturing enable even to prefabricate the various wood components, which will reduce construction time and further increase savings. The more detailed information could be found in [1] or in [2].

### 3.2 Natural insulating building materials

Choosing the insulation for the building is the one of the most important decisions to be made relative to the environmental impact of the building because insulation reduces energy consumption. Various synthetic and mineral insulating materials typically create potential health hazards and can also consume a great deal of energy when produced. There are, however, many alternatives available today and in most cases it is quite possible to avoid using materials that are environmentally damaging or which create health hazards either in their manufacture or their installation [1]. The alternatives that can be recommended are cellulose, softwood fiberboard, wood wool, flax, hemp, straw, lambs wool, reed, cork, cotton, coconut fiber, perlite, vermiculite, expanded clay, cellular glass, mineral foam or other insulations.



**Fig. 1** Passive House A - filling the cavity of the roof with cellulose insulation



**Fig. 2** Passive House B - wood frame structure. The skeleton was made from box-joist members

## 4 The passive house - the most sophisticated form of energy-efficient building

The most significant factor in terms of impact on the environment is energy use in buildings. It would be possible to reduce energy consumption in buildings by more than 80% at a fairly modest cost. Energy conservation strategies promote to increase building insulation values, airtight construction, high-tech window glazing and installing many other energy efficient building technologies such as air conditioning systems. The passive house is a most sophisticated form of low-energy house, which requires very little heating energy. The total energy consumption of such house is less than 15 kWh/square meter of annual domestic heating energy. The passive house requires much smaller active heating system to meet its heating requirements. By using building materials derived from renewable raw materials and the Passive House technology, the consumption of the resources during the construction of a building could be minimized by factor 10 as compared to conventional construction methods according to state-of-the-art technology [2]. There are two Passive Houses built of wood and natural building materials presented in this contribution. Both of the houses were optimized with “Passive house planning package” (PHPP). This software is a standard tool for planning and quality assurance of Passive Houses. According with calculation of the PHPP Passive House A reaches specific heat requirement 14,8 kWh/(m<sup>2</sup>a), Passive House B 14,2 kWh/(m<sup>2</sup>a).

#### 4.1 Passive House A near Bratislava, Slovakia

The external form of the building reacts to the local situation of the property. Solar energy is well utilized through optimal orientation with respect to the sun and by means of a solar collectors array. The first floor is rotated to south, so that it receives more direct sunlight. Solar collectors are fitted to the façade, what adds interest to a building design (**Fig. 3**).

The first floor of the house is built as a wood frame construction made from pre-assembled components and structural elements. Stress-skin timber panels allow entire walls to be prefabricated and assembled very quickly, what means high degree of standardization and therefore lower material and labor costs. The interior walls perform supporting functions. Ceiling joist are made from stacked wood strips. Flat roof is framed with framework tie-beams walled with fish plates. The space between all the exterior framing members could be easily filled with insulating material from cellulose, what is at present the leading organic recycled insulating material in Slovakia (**Fig. 1**). Cellulose was blown under pressure into cavities to form of dense blanket completely filling the void, what ensures to create a seamless cushion. The aluminium-clad wood windows have frames with insulated profiles made from cork insulation and triple glazing. The façade of the first floor was given an outer shell of untreated larchwood boards (**Fig. 4**). Thanks to high resin content is this wood very resistant and does not need protecting against weathering or pest attack. Chemicals are therefore not needed to preserve this kind of wood.



**Fig. 3** South view of the Passive House A



**Fig. 4** West view of the Passive House A

To ensure an airtight building without thermal bridges a number of basic rules were followed. The real problems occurred at the transitions between lightweight structural elements of the first floor and the solidly built walls of the ground floor (**Fig.5**). The sheeting from composite oriented strand boards (OSB) in the wall framing and roof serves its purpose as the internal vapor and air barrier. The layers of sheeting are overlapped and fixed to each other with special adhesive tapes. The same method was used for the transitions between sheeting and plaster. The air barrier was not penetrated by electrical wiring of plumbing. At some places the leakages were avoided using special gaskets fixed around the piping. Leakages were also avoided in the exterior water proofing, what will not allow air to penetrate into the insulating material. The windows were installed also correctly, the slim spaces were insulated and the air barrier made to overlap the edge of the frame. The airtightness of the building shell was measured with the Blower-door test and the leakages were localized and eliminated. The thermal bridges were calculated using software THERM 5.2 and were included into the PHPP calculation. A thermal bridge of horizontal console from wood strips was taken into account during the construction(**Fig.6**).



**Fig. 5** Transition between lightweight structural elements and the solidly built wall



**Fig. 6** Calculation of the linear thermal bridge loss coefficient.  $\Psi$ -value = 0,008 W/(mK)

#### 4.2 Passive House B near Bratislava, Slovakia

This is one of the very first houses in Slovakia to be built on ecological principles, as a wood framed house with a solar energy collectors and rainwater plant. The project was directed according to environmentally friendly methods of saving on resources and energy. This house was built with post-and-beam technique. The wood frame structure allows for a variety of floor-plans by virtue of its modular design. Costs are kept low by using of prefabricated components. With small cross-sections less material was used and less weight of wood construction was reached. In this way wood components could be made more affordable and more resource efficient. The advantages of these wall sections are that they are relatively inexpensive, do not cause thermal bridges and they have a better coefficient of vapor diffusion. The vapor diffusion ability of the shell is not be diminished because of use of sturdy, but permeable natural materials. The building structure consists of a skeleton made from box-joint members of 40 cm thickness with an exterior and interior wall sheathing material to provide lateral stability (**Fig. 2**). Box-joints were utilized as to construct an extremely well-insulated wood frame with relatively thin walls. Gable roof is framed with similar box-joints. Ceiling was constructed with joists with a sub floor on top. The structural elements have been cut and assembled in the manufacture. The house was erected on site in a relatively short time and with less cost. As an interior sheathing and by the manufacturing wood timbers and beams were used OSB boards. Interior ceiling was finished with gypsum wall boards. The exterior sheathing, wind- and waterproofing layer is made from medium density fireboards (MDF), what will not allow air to penetrate into the insulating material (**Fig. 7, 8**).



**Fig. 7** East view of the Passive House B



**Fig. 8** West view of the Passive House B

For the wall and roof insulation cellulose was used. It was filled into the cavities between the joist and rafters. Additional thermal insulation was applied to the building exterior - on top on the rafters and external walls one layer of fiberboards made from softwoods laid was fixed. Soft fiberboard provides good phase shifting of summer heat, so the inside of the house does not become unpleasantly hot. Softwood fiberboards were also laid underneath the flooring to provide natural sound insulation. As a loose-fill insulating material for floor the new natural granulate Siopor is used. Siopor is produced by heating the base material (silicate sand) to around 300 °C, which expands multiple times its original volume. The part of the interior walls will be built from loam (unburned clay) bricks, what will ensure pleasant living environment. Loam products have excellent heat storage and moisture regulating properties. The part of the interior surfaces was plastered by premixed clay content plaster, applied on reed matting. The floor coverings from natural materials without synthetic resin adhesives as wood, ceramic tiles and natural cork will have a positive influence on the room micro-climate, because they will not either contaminate the surrounding air, or build up electrostatic charges.

## 5 Conclusions

The criteria by which our homes are judged are not just esthetic - ecological considerations are increasingly determining the directions taken by architecture, building methods and lifestyles [1]. This contribution contains a systematic survey of the various aspects involved in ecological architecture, a factual discussion of appropriate construction techniques and, for the first time, an evaluation of all current natural building materials used in Slovak conditions. The topics discussed range from choosing the plot and suitable construction method to design Passive Houses built of wood and natural building materials. The extensive and constantly expanding body of knowledge about the conditions governing the internal climate of buildings, the development of solar technology, and the scope for simulation, calculation and measurement should be also used. This is the precondition for the creation of modern architecture. Accomplishing this will require a much more flexible approach to planning and living in general.

## References

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