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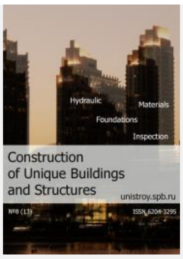

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Passive houses in Finland

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ABSTRACT

Since the first passive house was built in 1991 in Germany the idea of low energy buildings goes around the world. The standard of passive houses was developed in middle Europe but also in countries with latitudes over 60° people was trying to realize building which "heat themself".

The standard was adjusted for colder climate and different techniques were getting invented to keep the houses in artic conditions warm. Among others in Finland passive houses are built nowadays and getting more and more popular.

A good insulation, an efficient ventilation system with heat recovery and clever devised heating systems make a passive house efficient and rentable. The invest is mostly not more than 10% higher as a usual building and the payback is often after 6 years already achieved [15].

Contents

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1. Introduction

Energy efficiency is a widely discussed issue nowadays. Energy will be getting more and more expensive and European countries want to reduce the emission of greenhouse gases. Around 30% of the overall energy consumption is used in private households. So it looks natural that also in this sector more and more energy should be saved and there are a lot of ideas to save energy in residential buildings. One of these is the development and building of passive houses. Passive house is a building which consumes a minimum of energy by means of its constructive and engineering futures and does not need a traditional heating system. The main principle of designing of this type of house is using all methods of heat storage. And it is necessary in such kind of buildings to provide all the energy by means of alternative energy sources.

2. Passive House and its future

Passive house is a low-energy building. It has several features and devices which contribute to very low energy consumption and at the same time high living comfort. It is so air-tight and well insulated that a regular space heating is not needed. The heat loses are so small that they can be nearly compensated by heat gain from occupants and household activities. The energy sources for a passive house should be renewable energy since the idea of this building was to be sustainable.

3. "Passivhaus Standard"

The "Passivhaus Standard" is a standard developed by the "Passivhaus Insitut" in Germany, setting requirements for a building to be a passive house. According to the Passivhaus Standard a passive house is "a house in which space heat requirement is reducing by mean of passive measures to the point at which there is no longer any need for a conventional heating system; the air supply essentially suffices to distribute the remaining heat requirement" [1]. According to this standard the maximum heat requirement was calculated to 15 kWh/m2 per year. But as the standard was published in Germany the question is if it is possible to achieve these requirements in Finland where the outside temperature in the middle and the minimum is much lower compared to Germany. The Passivhaus Standard also defines the U-values for the main buildings structure. So there are following: <0.15 W/(m2K) for opaque elements and <0,8 W/(m2K) for windows and translucent elements. The supply must have a temperature of min 17 °C and the heat recovery must be transfer at least 75% of the heat from the exhaust to the supply. The infiltration rate by over and under pressure of 50 Pascal (n50) must be lower than 0.6 1/h. The use of specific primary energy for domestic application should be lower than 120 kWh/m2a [2].

In countries with cooler climate, the regulations are often different. To embrace the harder weather conditions the regulations for a passive house are different. But not in all Nordic countries the standard is less strict. In Norway they use the same values then the original Passivhaus Standard in Germany. In Sweden the standard gives just requirements for the heating power and not for the energy consumption. Depending on the size and the latitude the heating power is bounded to 10 – 14 W/m2. By a full heating time of around 1500 h/a the energy consumption should be nearly like the German standard required. The infiltration (n50) is with 0.3 l/(s m2) given. With a room height of 2.5 m this equals an air change rate of 0.43 1/h. In Finland, the Standard is different and less strict. The country is split in three zones with different weather conditions, South coast, central and Northern part. In the south the values should be following: <20 kWh/(m2a) for the heating demand, <130 kWh/(m2a) for primary energy consumption for all domestic applications. In the middle and the northern part the heating demand and the primary energy could be each 5 kWh/(m2a) higher. The infiltration rate is also defined to 0.5 1/h [3]. For the several elements the Finnish definition of a passive house does not give specific instructions. Anyway, the "National Building Code of Finland" gives regulations for any new building. So the U-values have to be at least as following: outer walls 0.17 W/(m2K), ceiling/roof 0.09 W/(m2K), base floor 0.17 W/(m2K) and the windows 1.0 W/(m2K). Every Finnish newly build house have at least already nearly the same thermal insulation quality of a passive house as in the middle Europe. And also the compulsory airtightness (q50) with 2 m3/m2h (by room height of 2.5 m n50: 0.8 1/h) is in the same range then the German "Passivhaus Standard" [4]. Just the thermal conditions in latitudes over 60° makes it not possible to achieve the standard. For example had the German city Erfurt in middle Germany in the last five years an average of day degrees of 1800 and the city Jyväskylä of 3500. So the thermal conditions make it necessary to insulate the building more than the German / International standard say to get nearly the same results.

Anyway, the future to create a passive house is everywhere in the world in the end same. And not only a good insulation, airtightness and reducing of thermal bridges are necessary to achive the standards, also some construction and engineering features which serve for reaching the aim to construct a passive house taking into account.

4. Structural features

As a passive house is a special building with its own standards there are some construction and engineering features which serve for reaching the “Passivhaus Standard”, also taking into account the cold climate conditions in Finland.

5. Passive solar design and glazing

The house should be situated in such a building site where it can gain maximum of sun rays in winter without any shading from trees and other objects. The south facade should be within 10 degrees to the west from the true south.

The next issue which must be taken into account is the amount of glazing and window orientation. The area of South oriented glazing should be 5-12 % of total floor area of the building. It is also necessary to take into account possible summer overheating. So for cold climates overhangs should be designed so that they can fully shade the windows on the Southern side during summer and not to shade the sun in winter time when the sun raise not that high.

The building material in passive solar design plays an important role, too. The materials with high thermal mass should be used, such as brick, stone ceramic tile, and concrete. These materials store heat and lose it very slowly. A certain amount of mass is added depending on the amount of glazing. So, for above 7 % of glazing for each square meter there are 5.5 m^2 for floors that receive direct sunlight. Therefore the maximum amount of mass for the floor is 1.5 times more than the area of South-orientated glazing. Certainly, passive solar design has to be decided along with other passive house features [5].

It is also very important to avoid irregular architectural shapes in the house’s design. “Dormers, roof-windows, bay windows, long narrow extensions to the main body, split levels, are all examples of features that cost energy in practice” [6].

Besides the orientation and overhangs, windows should have triple low emittance glazing and well insulated frames [7].

The “Passivhaus Standard” gives a very low U-value for windows which can be achieved only by triple glazing. Firstly, it is made for the comfort of occupants, because during winter the coldest surface will be the window. Since the passive houses does not have any heat emitters it is very important that the temperature difference between the coldest surface (window) and the mean surface temperature in the room should not exceed 3 $^{\circ}$C. Many windows manufactured in Europe are certified by the Passivhaus Institut, so it is always better to use so called passive house windows to avoid uncertainty with required U-values.

Nevertheless, in cold climate passive solar design is not the main importance, because there are few sun shine periods in winter. So that’s why the main emphasis should be given to the building structure, notably on insulation of the building envelope.

6. Insulation

Insulation of a passive house plays the most important role in its heat storage. As it was mentioned earlier, the exact U-values for choosing the insulation for a passive house are given in the “Passivhaus Standard”. But in Finland the U-values must be even lower in order to meet the requirements for energy demands of German Standard. The modified U-values applied for cold Finnish climate are shown in table 1.

Table 1. U-values (W/m2K) for Finnish climate [8]

Wall	0,07 – 0,1
Floor	0,08 – 0,1
Roof	0,06 – 0,09
Window	0,7 – 0,9
Fixed window	0,6 – 0,8
Door	0,4 – 0,7

So compared to the National Building Code of Finland the U-values must be much lower to achieve the limitation for passive house. The insulation thickness in passive house in Finland would be: for walls 500 – 600, 700 – 800 mm for the roof and about 400 mm for the floor. Since the ground in Southern Finland freeze down to

1.5 meters and in Lapland to 2.5 meters there should be a lot of attention on insulation of the floor structures and floor external wall connections [8].

7. Thermal Bridges

Heat losses through the joints, corners and edges are usually higher than through the walls, the roof and floor. Besides the insulation the passive house should not have any thermal bridge, because of thermal bridges there are undesirable heat losses. There are a lot of solutions to minimize these thermal bridges, depending on a certain case. The “Passivhaus Standard” also gives requirements regarding this matter. So the coefficient of a thermal transmittance Ψ shouldn’t exceed 0.01 W/(mK).

8. Airtightness

One of the most important features of a passive house without which the house can’t be considered passive is air-tightness. All the insulation and correct glazing will be ineffective if there are air leakages through the building envelope. The value of airtightness set by the “Passivhaus Standard” is air leakage rate n_{50} = 0.6 h^{-1}, which means that air in a building changes 0.6 times per hour at an over or under pressure of p = 50 Pa. “The theory behind air-tightness is that you should be able to draw a continuous line around the inside of your house showing the air-tight barrier, returning to your start point without lifting pen from paper” [9]. To achieve airtightness it is not only the responsibility of designers. Here is a qualified workmanship needed along with building materials of a good quality. After the building envelope of the house is finished the airtightness should be verified by a so called blower door test. In this test a computer controlled fan produce an exact over pressure of 50 Pascal and measure the air flow out of the building by holding this pressure. After, the same procedure will be made by under pressure. With this test a good workmanship can be proved and a good and thigh building envelope guaranteed.

9. Ventilation System

The precondition for a passive house to meet the “Passivhaus Standard” is to use heat recovery unit in the ventilation system when the system itself is a mechanical supply-exhaust system. The air distribution type should be a cascade-flow ventilation principle. It means that the air is supplied to a room and the pollutions are removed efficiently. The flow direction is well defined. For the supply is normally a living or sleeping room used. Over direct connected rooms the air should overflow to kitchen, bathrooms or other rooms where a high humidity or smell can be arise. In these rooms the exhaust connection should be installed.

The “Passivhaus Standard” has set the efficiency of heat recovery units to be at least 75 % or higher. Since the temperatures in Finland are that low the risk of freezing of the heat recovery is very high. So defrosting or a limitation of the extract air is needed to prohibit a temperature of the heat exchanger of less than 0 °C. This reduces the efficiency extensively. Another opportunity is to increase the outdoor air temperature before it enters the heat exchanger. Preheating can be done actively, with a heating coil, or passively, with a so called ground heat exchanger as a ground loop system [8]. To avoid freezing of the heat recovery unit, the temperature should be more than -4 °C. Usually a system of air ducts with the length of about 40 meters buried underground on the depth of about 1.5 to 2 meters is used to connect the ground heat exchanger with main ventilation system [10]. In middle in south Europe this systems are also used to reduce the air temperature in summer. The air in the ground get cooled down to 8 – 12 °C. So arise a passive cooling system over the ventilation system with them usually no other cooling system is needed.

As an air change rate the “Passivhaus Standard” gives 0.3 to 0.4 times the volume of the building per hour, with a general recommendation of leaning toward a lower rate [11]. This contributes to a high indoor quality and low energy consumption meeting the requirements of the National Building Code of Finland, part D2 “Indoor Climate and Ventilation of Buildings”.

10. Heating systems

Since the heating loads of passive houses are very low, an ordinary heating system is not needed, therefore the heating system should be simplified. It is possible if the outer walls and windows have nearly the same temperature as the room air temperature, because of the low thermal losses over them. There is a wide variety of heat generation sources being used in passive houses around the world.

As written in the beginning, the energy source should be renewable. Ground source heat pumps are suitable for small power output. But also biomass can be a renewable heat source. Here can simple firewood, wood chips or pellets be used. Since Finland has a lot of forests this energy source has short transport distances and have a low primary energy factor. Finnish laws also guarantee a sustainable forestry that the tree population doesn’t decrease. Solar thermal systems, often used in central and south Europe, are only usable in the south and there only for very low power output since the time between sunrise and sunset in the wintertime, where the heat power is normally used, is very short. In Northern Finland this source cannot be used at all since the sun is there not shining for some days during the winter.

To heat a passive house there are a lot of different possibilities. Three of them will be discussed in this article. All of them include a solution for heating, ventilation and domestic hot water production.

11. Ventilation air heating

As a passive house needs low amount of heating energy, space heating can be provided by ventilation supply air without any additional water heating system. According to the "Passivhaus Standard" heating demands can be compensated with ventilation air heating but it is not a requirement. As it was mentioned above the ventilation system must be equipped with a heat recovery unit with high efficiency. Also there should be a backup system for heating the ventilation air. "Space heating demand in a passive house is typically met through passive solar gains (40 – 60 %), internal heat gains (20 - 30%) and the remainder (10-40%) needs to be provided from auxiliary heating systems" [11]. Usually the energy sources for this system are biomass, gas and electricity from renewable sources. The air heater is installed right after the heat recovery unit. The heat delivery to the rooms by air should be compensating the heat losses due to transmission and infiltration. And, also the ventilation losses must be taken into account. The supply air temperature of the air which is meant for space heating is limited to 50 °C and when the heater is turned off (in the summertime) the supply air should be about 17 °C [12]. With these temperatures it is quite enough to cover the space heating demands of a passive house.

12. Underfloor heating system

Underfloor heating systems can be a good alternative to cover heating demands in a passive house since it uses low temperature heat distribution. In the case of underfloor heating the heat emitter is the whole floor itself but not the ordinary radiator placed on the wall. So the heat distribution is from the floor upwards that reduces the risk of draughts and keeps vertical temperature gradient acceptable. The type of heating distribution of underfloor heating system is radiation and convection. All this provides the perfect thermal comfort of the occupants.

There can be two types of such kind of heating: electrical, using conductive wiring, or hydronic, using piping with water inside and pumps which force the hot water to flow [13]. It is more convenient and reasonable in our case to use hydronic underfloor heating for not to install different energy sources for space heating and domestic hot water.

The distribution temperatures in underfloor heating systems usually are 30 – 45 °C, that result in the floor surface temperature of about 26 °C [14]. In well insulated houses and with a high density of pipes in the floor the temperature can also be lower. The ideal heat source for such type of heating system is ground source heat pump. As lower the needed temperature is as higher is the COP of the GSHP.

13. Pellet stove and solar combi system

The third alternative is not to design any space heating system in a passive house but to manage it with a pellet stove, placed in living room, for example. The fuel for such kind of stove is pellets. It is a sawdust based product pressed into the form of pellets [13]. Pellets are renewable and have a low primary energy factor.

Pellet stoves are usually very efficient (up to 80 – 90%) and have high energy content of around 5 kWh/kg. Most stoves are equipped with an internal fan which doesn't allow the heat to keep inside the stove [13]. In the case of the passive house a pellet stove can also provide extra heat for a domestic hot water along with solar collectors. It is sufficient especially when the hot water tank provides heat for the ventilation air. A stove with approximately 3 kW heat output can be enough for both space heating and DHW needs in a passive house. Otherwise there is a risk of overheating since the passive house has very low heat losses [11]. The stoves are controlled by thermostats which control the heat power by controlling the amount of pellets getting burned in time.

14. Conclusion

The "Passivhaus Standard" was developed in a warmer region than Finland, but the practice shows that there is a possibility to use this technique also in the cold climate conditions of Scandinavia. Just some small changes in the requirements must be taken to realize a building with very low energy consumption. Dozens of examples show that it is possible to build low energy houses in latitudes higher than 60°. The costs for construct a passive house are normally higher than to build a "normal" house, but studies shown that the payback is already after 0 – 6 years [15]. So after max 6 years the more invested money should be back in the pocket of the investor and the passive house get profitable. With the increasing costs of energy the payback time will be getting lower and saved money after this time will increase. In the future, passive houses will be getting a better and better investment.

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Пассивные дома в Финляндии

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ИНФОРМАЦИЯ О СТАТЬЕ

История

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Ключевые слова

пассивный дом
геотермальный тепловой насос
воздушное отопление
теплый пол
пеллетный котел
энергопотребление
мощность отопления

АННОТАЦИЯ

С момента первой постройки пассивного дома в 1991 году в Германии идея строительства домов с низким энергопотреблением получила широкое распространение в мире.

Стандарт на строительство пассивных домов был разработан в Западной Европе со средними широтами. В странах, находящихся за пределами 60° с.ш., была также предпринята попытка разработать концепцию здания, которое бы «отапливало само себя». Стандарт был адаптирован для более холодного климата с применением различных технологий для поддержания тепла в домах.

Именно эффективная теплоизоляция, система вентиляции с рекуперацией тепла, рационально подобранная схема системы отопления и позволяют пассивному дому быть энергоэффективным и рентабельным. Капитальные затраты на строительство пассивного дома не более чем на 10 % выше, чем для обычного здания, а сроки окупаемости составляют 6 лет.

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