International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 7, Issue 12, December 2018)

Passive House. Concept Description

George-Lucian IONESCU[1], Gheorghe Constantin IONESCU[2]
[1,2]*University of Oradea, Romania,*

Abstract: **This paper has the purpose of defining the concept of "passive house", alongside the energetic advantages such a building has. The content presented herein outlines the main focuses of passive house construction procedure, describing the notion of „building envelope", as well as base notions regarding the sealing method of a passive house by means of eliminating the negative thermal bridges.**

The paper ultimately presents conclusions in regards to full scale implementation of the passive house concept for the purpose of increased energy efficiency and the creation of a natural ventilation system, a primary concern in order to ensure a proper thermal comfort environment.

***Keywords*: passive house, energy efficiency.**

I. Introduction

The idea of developing a passive house first came from the Swedish professor Bo Adamson. During a study trip to China, during the mid 80s, he saw the traditional construction techniques utilized around the Yang Tse river area. The proof of these techniques has inspired the joint aid of Professor Wolfgang Feist to further develop the passive house concept. The very first passive houses were built in Germany during the 1990s. The number of built passive houses has increased over the course of the decade and has led to the establishment of the Passive House Institute at Darmstatd (Feist 2005).

II. Defining The Passive House

The house that is capable of maintaining a comfortable temperature, even during the cold seasons, without the use of a specific heating system is known as a passive house. The term "passive" is used because the main heat sources are the sun and the heat emanated by the actual inhabitants of the house, the heat emanated by the household appliances and by the heat that is passively consumed by the house without the use of special heating apparatus (Schneiders 2003) [4].

Through the term "passive house" we understand a house that has a maximum yearly heating requirement of 15 kWh/m^2 (Husbanken 2004). This standard has been developed for the first time by Wolfgang Feist and has now been regulated by the German passive house institute, Passivhaus.

The standard is exclusively defined by the required energy consumption for heating without having specific requirements for used construction materials and used construction techniques. Even if the standard is defined by the required energy consumption for heating purposes, the concept of a passive house also entails the reduction to a minimum of the energy consumption in regards to other sources of energy consumption within the building. In a regular fashion, this includes heated water and household appliances. The objective is to maintain a total energy consumption of 120kWh/m^{2}a (Schnieders 2003).

Although the standard itself does not establish any particular requirement for used construction materials, it is obvious that a reduced energy consumption cannot be realized without a deep take into consideration of all these aspects during the preliminary phase of the building's design stage.

Approaching the passive house concept has at its core five primary elements. Three of these (superior thermal insulation, heat recovery and solar power support) refer to the building's heating properties, while the last two (electrical potential and the completion of other energy requirement points with renewable sources) are necessary for completely minimizing the environmental impact [3],[5]. One of the conditions for attaining the established standards of the passive house concept is a thermal insulation level of the highest quality. This can be realized by means of using diverse types of materials, but the U values of the exterior construction elements must not exceed 0,15W/m²K. This can be accomplished by means of a superior thermal insulation, with a thickness of the thermal insulation layer between 30cm. and a maximum of 50cm.The thermal bridges are another important element that must be taken into consideration. These must be avoided by means of ensuring a perfect air tightness for the building. In order to ensure this performance, an in-depth detailed design process is required.

The main element in attaining the standards of a passive house is an efficient heat recycling system. According to the C107/1-1997 standard, in Romania, the number of air exchanges per hour has a value of 0.6, while in Norway this value is approximately ⅛ according to the annual Norwegian construction code.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 7, Issue 12, December 2018)

The recovery rate for heat must not exceed 75%, which can be attained by means of heat exchangers. The ventilation system must be extremely energy efficient [3],[4],[5].

The key factors for the realization of construction boasting the highest level of energy efficiency are the thermal insulation and the heat recovery system. The next step in this process is represented by the passive solar energy inputs. Approximately a third of the whole energy requirement of a passive house is covered by the solar energy input provided in a direct fashion by the windows. This is accomplished by means of having extremely low heat losses in the window areas, sockets of an extremely high efficiency and positioning of the windows towards the South. The U value of the windows must be less than 0,8 W/m² K, representing a bit more than half of the average value of a modern window.

In order to obtain a high electrical potential, it is required that only certain electrical devices be used that have a high level of electrical efficiency, classified as class A, according to the EU electrical efficiency standards. Even if a passive house is conceived for the minimization of the energy consumption, it will still have need of electrical energy. A passive house should also take into account obtaining such energy from renewable, non-pollutant sources. A good example would be the integration of solar collectors in the design process of the building, thus allowing an increase in the heated water percentage that can be passively heated [4].

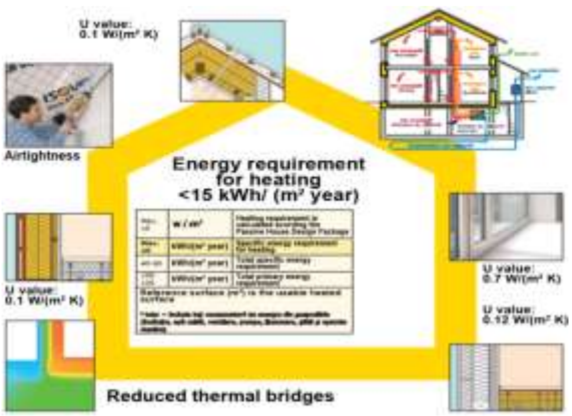


Fig. 1 Passive house schematic presentation

III. Conditions Regarding The Design Process Of Passive Houses

A. Benchmarks regarding passive house designing

Benchmark: an energy requirement for heating of 15 kWh/m^{2}year. Where this is implemented, the economy, construction physics and the design are in perfect harmony. Judging only by its outside aspect, a passive house can be very similar in aesthetics with conventional design models. In regards to the interior, an in-depth design process is required. This stage is more pretentious and costly, at least in the early stages. Ultimately, the new concept will facilitate the development and will aid in reaching an advantageous energy quota: on one side, reduced heat losses, on the other side, increased solar heat and internal heat inputs. Both the designing and execution of passive houses must be made with a maximum of professionalism. A passive house has a limited "energy budget", its energy potential being guaranteed for multiple decades [2], [4], [7]. In the long term, the quality of the execution is even more important for the building's energy efficiency than the U values that are calculated for each structural component.

Because conceiving a passive house is a very pretentions work, that requires an in-depth project and high-quality execution methods that are very well controlled and overseen, the development of a passive house becomes easier. In order to reduce the cost of building a passive house, it is recommended that a simple and compact design be chosen. Every exposed or prominent part of the building increases the heat requirement for heating. From the geometrical point of view of the building, it is advantageous to minimize the envelope surface of the building, which limits the heated volume of the interior. Reducing this surface diminishes the heat losses and construction costs. Furthermore, in regards to the shape of the building, the location can have a positive impact over the energy consumption. A passive house must be facing south.

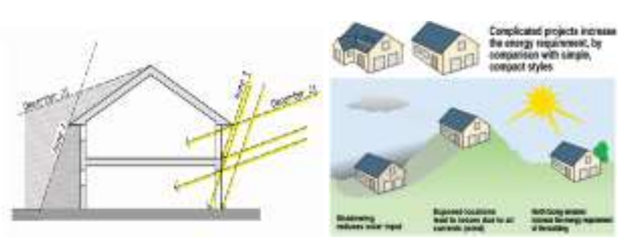


Fig. 2 Aspects regarding orientation, inclination of solar beams and shadowing

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 7, Issue 12, December 2018)

Thermal bridges are weak points of the building's envelope that lead to unwanted heat losses. In conclusion, an absolute priority must be given to building an envelope that has no thermal bridges.

B. The most important steps in designing are:

- Reducing shadowing (or shadow casting) during the winter season. This means designing without guardrails or bulwarks, exterior protections, encased balconies, divider walls etc.
- The building's structure must be compact. Glassed or windowed surfaces must be facing south and cover at least 40% of the wall's surface. East/west/north facing windows must be small, no more in sized that required for attaining an optimal ventilation.
- The shape of the envelope must be simple, without complications.
- Concentrating the installations in a single space, such as positioning the bathrooms above or in the vicinity of kitchens.
- Outlining the locations of the necessary ventilation pipes.
- Thermal separation of the 1st floor sublevel (including the stair to the sublevel) - completely airtight, without thermal bridges.
- Estimating, from the beginning, through calculus the energy requirement (i.e. calculus through the Pasive House Design Package PHPP).
- Selecting the structure type of the building - light (wood, metal) or heavy (concrete, brickwork). Establishing the project's concept, house plans, energy supply concept for ventilation, warm water heating.
- Designing the thickness of the envelope's insulation and avoiding thermal bridges.
- Designing the link elements as airtight and without thermal bridges.

C. The building's envelope

The building's envelope is very important in the design phase of a passive house. The V/A ratio must be between 1 and 4 and the A/V ratio must be between 1 and 0.2. Because heat can be lost by means of transmission through the envelope, it having a compact shape can ensure a superior energy performance due to a reduced surface size [4], [5], [7].

Not only can the shape of the building, but also the location chosen for it can have a positive impact on the energy consumption. The passive house must be faced south, without shadowing provided by mountains, hills, trees or other buildings so that the solar energy supply is maximized, especially during the cold winter months.

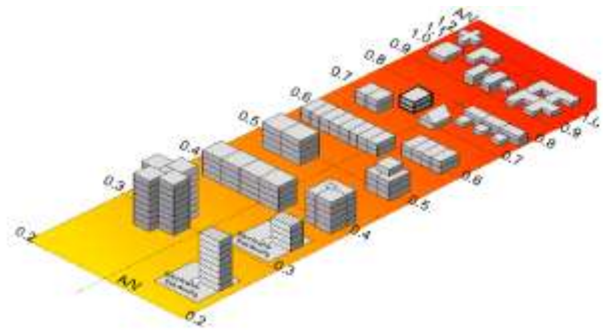
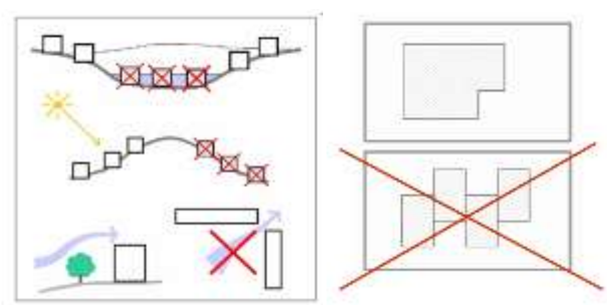


Fig. 3 V/A and A/V ratio



a. **b.**

Fig. 4 Choosing the a) location and b) the shape of the passive building

D. Thermal insulation

A passive house is possible for any type of construction, be it massive, made of wood, glass or a hybrid structure. If the different components have been carefully installed, without thermal bridges, a closed system will result, that can keep a comfortable interior ambient temperature. The building's envelope being airtight offers protection against the cold, heat and noise. The building's tenants can enjoy the best possible comfort, due to the very small difference in air and surface temperature both during the winter and summer.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 7, Issue 12, December 2018)

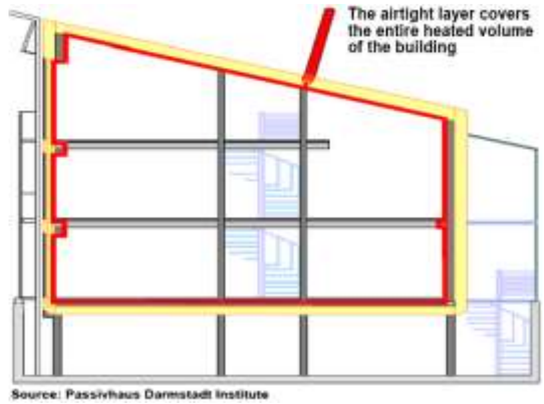
The insulation layer continues from the roof to the foundation and will not only reduce costs but also represents a useful investment in regards to tenant comfort. Thus, the mineral fiber-based thermal insulation materials such as mineral cotton, have outstanding results. For comparison, in order to obtain the same insulation effect as 1.5-2cm of insulation material, it would require approx. 30cm of solid brick or 105cm of concrete. Taking the recommended insulation thickness into consideration, 30cm or more for passive houses, the weight over the building would be too great, that is not mentioning the costs as well. Another important aspect is represented by the very favorable ecological consequences that exist when using mineral cotton: less energy for heating, reduced CO_2 emissions and a longer lifespan for the building [4].

All these things are beneficial both for the tenants but also for society.

Only through installing a high quality insulation can the solar energy be used efficiently. During the winter, the solar energy supply is capitalized within the house, instead of pointlessly heating the outside air. An economically optimized solar system within a passive house can cover approx. 30-50% of the total low temperature heating energy. The windows also contribute to reducing the ambient impact. If they conform with the passive house standards, then they can output more heat toward the interior than they do toward the exterior. Due to triple layered windows, the thermal insulated sockets and lack of thermal bridges, the heat output levels are greater even during the winter, thus they can compensate a large part of the heat losses. Although, in order to ensure the tenants do not overheat during the summer, special precautions must be taken:

- Shadowing the windows that face south, east and west
- Measures for screening the windows that face south, such as by means of installing a more prominent eaves
- The walls of the rooms must have a good heat retention capacity
- Ensuring an efficient ventilation

E. Airtightening a passive house



5 Passive house airtightening

In a passive house, air exchange must be controlled. If this is not done, it will generate heat losses, air currents, condensation risk, pointless heating etc. A continuous airtight envelope that outlines the passive house from the roof all the way to the foundation avoids these unwanted effects and allows a comfortable living condition and reduced energy consumption.

The airtight and insulated walls can breathe as well as regular walls, the ventilation system always offering fresh air of the best quality. Depending on needs, the windows can be of course opened. Controlled ventilation especially vis-a-vis an uncontrolled one is a requirement not only meant for passive houses. Working by means of solar energy and equipped with a heat pump and an air-to-air heat exchanger, the system ensures a continuous and permanent supply of fresh air in all rooms. At the same time, it also establishes an energy efficient air distribution as well as a heat recovery system. In regions that boast cold winters, the airtight layer that also server as a protective barrier against vapors is always installed on the warm side of the insulation. The bridges that are not airtight and pass through the building's envelope have undesired consequences, generating heat losses, uncontrolled air flow, weak sound insulation and structural deterioration possibility.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 7, Issue 12, December 2018)

It is thus imperative that the overall airtightness be planned from the preliminary design phases, that take into account all the connections between the structural components, wall mergers and passes through the envelope.

For the wood based structures, it is recommended that a supplementary layer of thermal insulation be installed on the vapor barrier that faces the inside of the room.

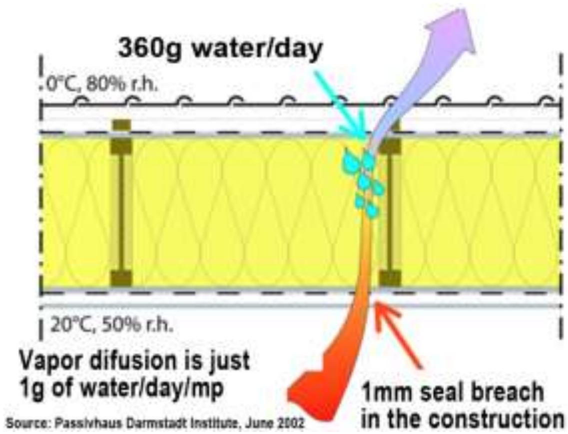


Fig. 6 The effects of poor airtightness within the structure

The flexible climate membrane system can adapt its properties depending on the season. During the winter, it blocks humidity that protrudes from the interior and during the summer it allows the evacuation of water vapors in all directions. This ensures an ideal function as a vapor barrier, protecting against wetness penetration in the walls and roof, protects and structure of the building and brings a bonus level of comfort in the living space [1], [4], [5].

Verifying the airtightness is an essential element for the quality certificate of a passive house. It is absolutely necessary that this test be done before the interior building envelope is completed, so that each execution point can be detected in a timely fashion and where applicable remedied with relatively low costs. The Blower Door test is used in order to detect air leaks through the building's envelope. The lower the measured value is, the higher the airtightness level is. Passive houses require a value of 0.6. This means that during the test at most 60% of the interior air volume can escape though the envelope, during the course of one hour. Experience has demonstrated the values between 0.3 and 0.4 can be attained.

A very important aspect for passive houses is the careful execution of the building's envelope.

Due to this fact, the chosen construction materials must be crafted in optimal conditions. This often entails developing the airtightness of components during dry weather, their substrate and edges must be dry and lack any form of dust. All joints between adhesive tapes and porous materials must be penetrated with a primer layer, and in order to protect the structure the airtightening tape of the components must be able to resist water and wetness infiltration. An important safety element is the quality of joints. An airtight joint between two sheets of insulating membrane cannot be made by means of point based merger. The two sheets need to be overlapped and the merger area needs to be airtightened with the corresponding adhesive tape. Applicable for both traditional buildings and those based on light structures, it must be taken into account that any pass through the insulating membrane can result in heat losses and condensation danger if the respective zones have not been well insulated.

Fig. 7 Blower Door test

Fig. 8 Frequently encountered types of lack of airtightness

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 7, Issue 12, December 2018)

Fig. 9 Thermal images showing improper airtightness and heat loss

Fig. 10 Roof airtightness

F. Negative thermal bridges

The effects of thermal bridges must be reduced as much as possible. In this sence, passive houses present the advantage of thicker insulating exterior walls (20-40cm). Due to this linear coefficients of heat loss can be valued at approx. $0,06W/(m^2Kt)$ when they are calculated based on the exterior dimensions of the building, the result being a bonus for the total heat loss calculations. These "negative losses" will compensate a part of the "positive losses" that are associated to the other thermal bridges of the building.

A viable method for detecting thermal bridges is the graphical representation of diverse building projections. Studying the plans, sections and detail planes can help detect discontinuities present in the exterior envelope. In the first case, the installed thermal insulation layers need to be marked with yellow. After that is done, the areas in which the yellow line that outlines the building is interrupted must be identified. These are the weak bridges that can create thermal bridges. After that, an analysis must be made to see if said bridges can be eliminated by means of structural modification or if new solutions can be made in order to minimize their impact.

Any punch through the insulation layer represents a thermal bridge that increases the heat losses and the deterioration rate of the structure.

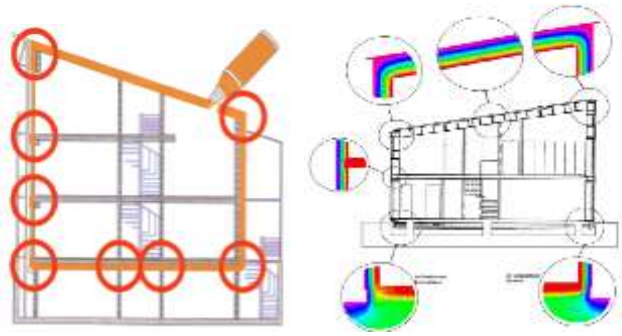


Fig. 11 Identifying the thermal bridges

The thermal bridges that are most frequently generated are usually found through or in the vicinity of structural elements of the building (rafters, battens, anchoring elements etc.) and must be analyzed under the U ratio of said elements. In these elements of the building, high heat losses are produced, that can also lead to the deterioration of the building. Non-homogenous qualities of a brick wall behind a continuous insulating layer can be ignored if the insulation layer has been sufficiently sized [4].

G. Solutions for avoiding thermal bridges

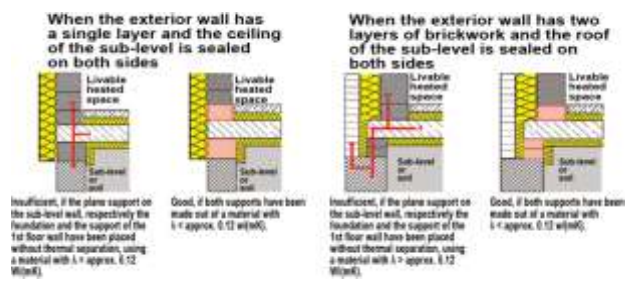


Fig. 12 Thermal bridges at the joint between sheets over the sub-level or sheets layered over the soil and exterior walls.

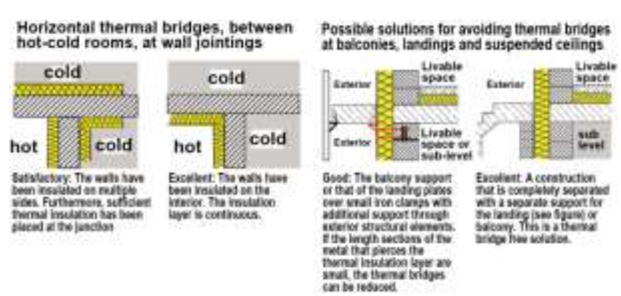


Fig. 13 Thermal bridges at the joints of horizontal walls

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 7, Issue 12, December 2018)

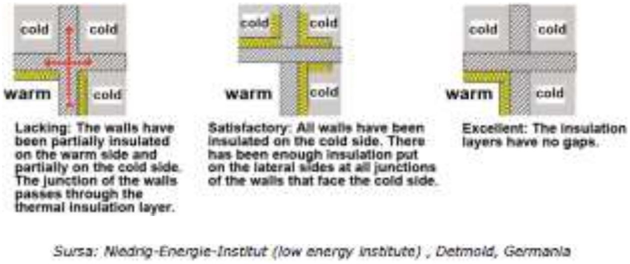


Fig. 14 Thermal bridges at the breaks of horizontal walls

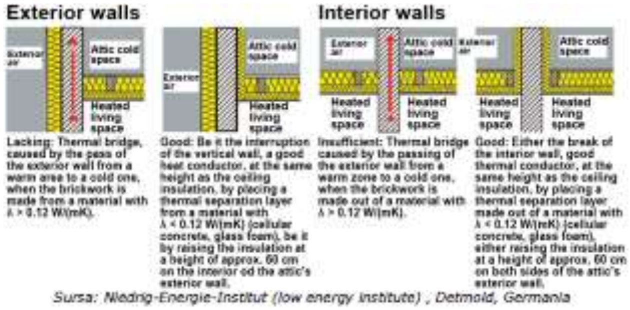


Fig. 15 Thermal bridges at the breaks of vertical walls

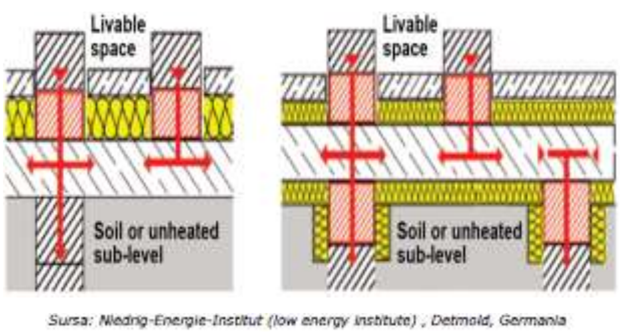


Fig. 16 Thermal bridges at the joints of sheets over the sub-level or sheets layered over soil and interior walls.

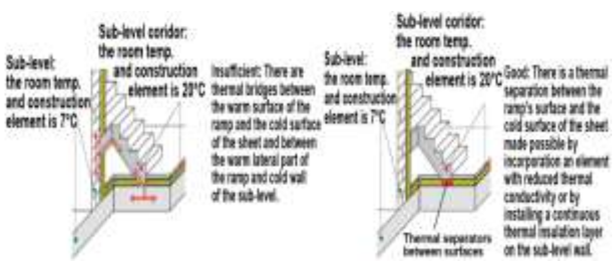


Fig. 17 Thermal bridges at the joints between stair ramps and thermal separation walls or sheets layered on the soil

Punch through the building's envelope by the installation piping, windows or doors is inevitable. Due to this reason, thermal bridges can never fully be avoided. Thus, it is imperative that the points in which these are produced to be carefully calculated in order to minimize their effects. The higher the thermal insulation level is, the more important the relative weight of the losses by means of thermal bridges is.

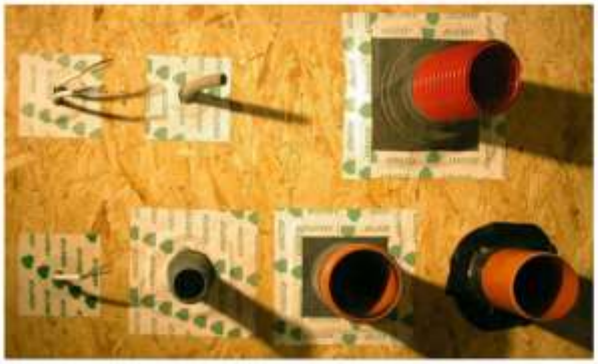


Fig. 18 Installation airtightening

Fig. 19 Window airtightening

In order to impede that the heat be transmitted through the foundation or through the sub-level waoo, the foundation needs to be fully thermal insulated.

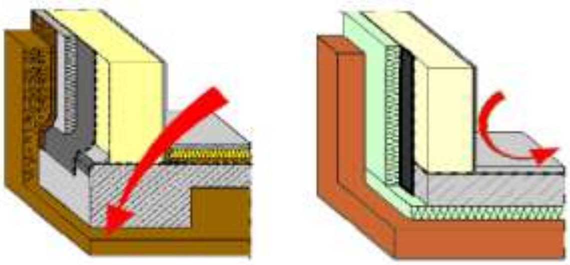


Fig. 20 Thermal insulation below the foundation

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 7, Issue 12, December 2018)

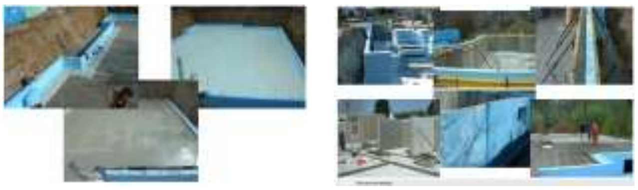


Fig. 21 Thermal insulation with extruded polyester under the foundation

H. The windows of a passive house

The windows of a passive house have triple layered windows and sound proofed sockets. Solar energy that can be obtained through these south facing windows overrules the heat loss though the windows, even during the winter months. Due to the superior quality of the glass, the measured temperatures on the surface of the glass are always close to the temperature of the interior air. The qualities of the triple insulated windows can be easily noted during the dark months of autumn and winter. At optimally designed buildings, the limited quantity of solar energy is utilized in such an efficient manner that the solar energy gains from the exterior are able to compensate the energy losses through the windows toward the exterior. If there is no sun present, this still does not pose a problem, because the high-tech insulating glass has a very low infrared emission. This means that the special window layer structure reduces the quantity of heat that is radiated by the building. The larger part of this heat is reflected back towards the inside of the building.

Fig. 22 Triple layered windows that are specific for passive houses

Fig. 23 Thermal insulated socket models

IV. CONCLUSIONS

Presently, the population of Central Europe spends over 90% of its time in enclosed spaces, where the average interior air quality is lower that of the outside air quality. Furthermore, this air contains the mos humidity and is contaminated with pollutants, odors and other effects. The remedy is the permanent exchange of air from the exterior that corresponds with hygiene requirements. The issue is that when air exchange is done by means of open windows (natural ventilation), the exchange rate of the air flow can not be controlled with precision. This presents large variations, in regards to outside temperature, wind direction and personal ways of ventilation. Another negative aspect is that heat that is lost by having the outward air-flow as a transmission vector cannot be recovered. Forced ventilation systems on the other hand can ensure a predetermined and constant exchange rate, they can recover the heat contained within the evacuated air and can ensure an even redistribution of said heat. A passive house does not need a separate room for housing the ventilation system. A compact ventilation unit the size of a refrigerator is fully sufficient in order to constantly provide fresh air and heat exchange for all the rooms, while evacuating stale air at the same time. The central unit is comprised of a heat exchanger, ventilators, filters and, if needed, an air pre-heater, air cooler and humidifier or dryer. The stale air from the kitchen, bathroom and WC is sucked through the evacuation system. Before it is evacuated to the exterior, it releases its heat within a heat exchanger and then heats up the fresh air that is induced from outside. This in turn will reach a temperature close to that of the room. It is presently possible to recover 90% of the heat from evacuated stale air. [3], [5]

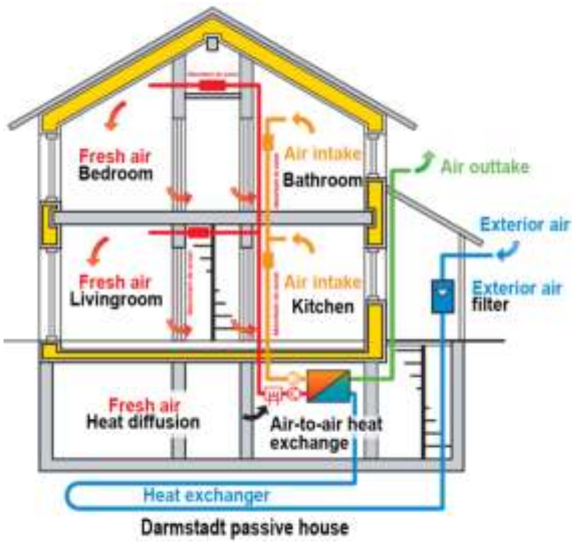


Fig. 24 Ventilation system [4]

REFERENCES

[1] Călușaru Ionela Mihaela, Costache Adrian, Băran Nicolae, Ionescu George-Lucian, Donţu Octavian 2013 A New Solution to Increase the Performance of the Water Oxygenation Process – Revista de Chimie 64, nr. 10, Bucureşti, pg. 1143-1145

[2] Coldea Speranţa, Ionescu, Gh. C. 2005 Elemente de fizica fluidelor şi hidraulică. Editura Matrix Rom Bucureşti.

[3] Gligor E., Ionescu G.L., Gavriş Daniela 2013 Mariana, Instalaţii pentru construcţii – Suport laborator, Editura Aureo – Oradea, 139 pg., ISBN 978-606-8382-36-4.

[4] Iancău Marcel 2013 Contribuții privind optimizarea energetică a clădirilor individuale de locuit din România – Teză de Doctorat.

[5] Ionescu George 2017 Lucian, Instalații pentru construcții, Editura MatrixRom – Bucureşti,ISBN 978-606-25-0311-6, 2.

[6] Ionescu Gheorghe 2008 Constantin, Ionescu Daniela – Smaranda – Increasing the efficiency of water supply systems by optimizing the electrical energy consumption - The 19th DAAAM INTERNATIONAL SYMPOSIUM "Intelligent Manufacturing & Automation" 22-25th October – Trnava, SLOVAKIA ISSN 1726-9687.

[7] Mirel Ion, Florescu Constantin, Girbaciu Alina, Girbaciu Cristian, Dumitru Pavel, Dan Sorin, Ionescu George – Lucian 2015 Effects of qantitative changes on drinking water quality indicators of urban distribution networks – Revista de Materiale Plastice, ISSN 0025 – 5289, Vol. 52, nr. 4/2015, pg. 504 – 509