Challenging the possibilities

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Abstract

In October 2012 we, *langenkamp.dk architects*, finished the project of an administration building for Blaakilde Boarding School in Denmark. As it was not possible to meet the Passivhaus requirements with the desired programme and within the budget, the aim was instead to minimize energy consumptions as close to the Passivhaus requirements as possible. This was complicated by a north facing orientation of the building and shadowing adjacent buildings towards East and South.

Afterwards we decided to follow up on the project and find out which implementations would have been needed in order to meet the Passivhaus requirements within these far from optimal conditions. *langenkamp.dk architects* have analyzed the energy calculations, optimized heat losses and components, to end up with a new energy design strategy. This will be presented along with the build project with its details, and an analysis of the additional needed costs to have implemented this new strategy in the building. The results show that it would have been possible to meet the Passivhaus requirements, but that not all of the needed improvements would be profitable.

Keywords: Architecture, design guidelines, energy design strategy, non-residential, optimization, cost-benefit, analyzing energy calculations.

Introduction

The architectural firm *langenkamp.dk architects* has specialized in passive-, zero- and plus energy architecture. The firm was founded in July 2008 by *Olav Langenkamp* who is the architect behind *Villa Langenkamp*, the first certified Passivhaus in Denmark and Scandinavia.

Olav Langenkamp has for a number of years worked with the construction of passive and low energy houses as well as industrialized buildings. The firm is currently working on projects in Denmark, Norway, Germany and China. The projects range from single-family passive houses and multiple passive house blocks of flats, to Passivhaus student apartments. *Olav Langenkamp* graduated as an architect from ETH (*Eidgenössische Technische Hochschule*) in Lausanne, Switzerland, in 1998 and has been certified as a Passivhaus architect by the *Passivhausinstitut* in Darmstadt, Germany. *langenkamp.dk architects* is a dynamic firm of architects with an international and national network of specialists within energy-efficient building design.

Objective

Is it possible to meet the Passivhaus requirements in a non-residential building, which has shadowing adjacent buildings towards East and South and only north facing windows, so there are almost no passive solar gains?

Figure 1 The existing administration building.

Build project

Blaakilde Boarding School is located close to city Tarm near the western coast of Jutland in Denmark. As part of a planned larger energy refurbishment of the school's class rooms and dormitories, *langenkamp.dk architects* were commissioned to design and detail a new arrival- and administration building, which is the first phase of this larger energy refurbishment. The new administration building is built on the foundations of the existing administration building, which can be seen on Figure 1, and has a treated floor area of approx. 225m^2. It shares two partition walls to adjacent school buildings towards east and south. Only the exterior walls towards north and west are exposed to ambient air.

As seen on Figure 2 below, the building opens up towards a green area and welcomes pupils and visitors through the glazed north facade, of which 70% therefore is window area. This high percentage of window area towards North will of course result in very large heat loss and cannot be justified energy wise. The brief from the client was although that the new administration building must continue the characteristics of the existing building, this including that the strong visual connection to the adjacent park should be preserved. Furthermore, as the building holds the offices and meeting room of both administration and teachers, the importance of transparency and that visitors and pupils have a visual contact to the staff, was stressed. These architectural aspects were given priority, which required considerably awareness on optimizing the energy performance of the other building components.

Figure 2 The glazed north façade of the new administration building.

Danish windows are used from Ecliptica, which is a triple glazed, outwards opening composite window with a frame width of only 45mm and a U-value of 0,71W/m^{2}K for a standard 1230x1480mm openable window [Ecliptica]. To further increase the amount of daylight in the rooms located farthest from the glazed north façade, five roof lights were installed.

Figure 3 Ventilation pipes on the existing foundations and roof lights.

As seen on figure 4 below, the existing foundations consisted of a base layer of compressed sand, 200mm of LECA functioning as the insulated layer with 100mm of concrete on top and flooring. This results in a U-value of 0,363 W/m^{2}K. As it proved expensive and unnecessary to demolish the existing foundations, it was instead decided to improve the insulation level, by raising the floor level as seen on the details. This extra height in the floor slab also provided a possible routing for the ventilation pipes. The installed ventilation unit is a Genvex GE Energy 3, which is a local Danish manufacturer. This unit has similar data as the Passivhaus certified Genvex GE Energy 1 with an effective heat recovery efficiency of $\eta_{HR,eff}$ = 76% [GE1].

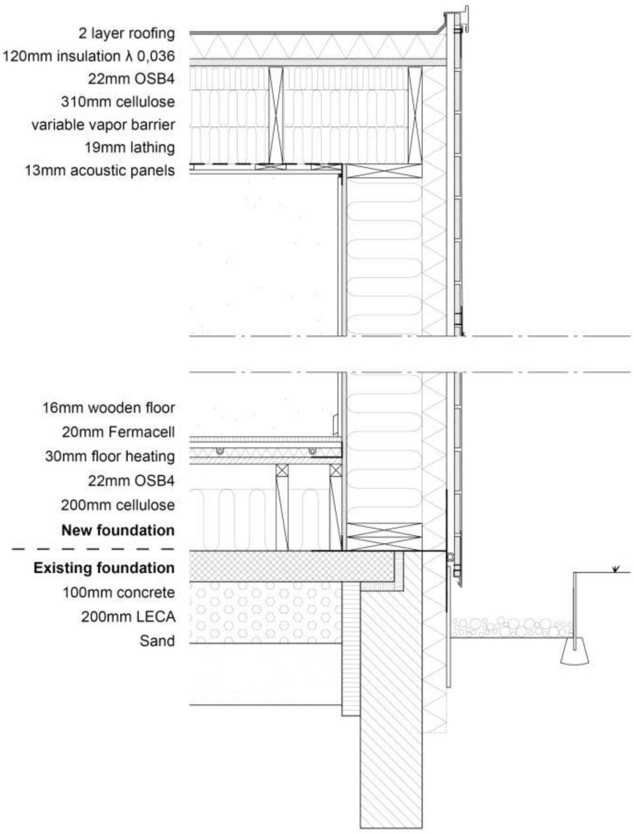

Figure 4 Details of roof, exterior wall, new- and existing foundation.

The details shows that a light weight wooden frame construction is used, with rigid wood fibre insulation boards in the exterior walls and loose fill cellulose insulation in the roof construction. This results in the following U-values of 0,120 W/m^{2}K for floor slab, 0,123 W/m^{2}K for exterior walls and 0,089 W/m^{2}K for roof.

Meeting the Passivhaus requirements

An initial PHPP calculation shows almost no available solar heat gains, with the transmission losses through windows in the north façade being three times the solar heat gains. And as the transmission losses through the 70% glazed north facade are 32% higher than the combined transmissions losses of all the other building elements, improving U-values of walls, floor slab and roof will have less effect than on the windows. In the same way, the calculations also shows minimal solar heat gains from the five roof lights. Although Passivhaus certified class A roof lights from Danish *Illumino*

Energy, were used, the calculations shows that the shadowing buildings towards East and South results in the roof lights having 55% higher transmission losses than solar heat gains. There is although potential in improving ventilation, as ventilation heat losses are almost 20% of the total heat losses. The following improvements were therefore made to meet the Passivhaus requirements:

- Ecliptica windows was replaced with Passivhaus certified *Pazen ENERsign* windows, which minimized window transmission losses with 9%.
- Ventilation heat losses were reduced with 45% by using a Passivhaus certified *Paul Novus 450* ventilation unit and reposition the unit resulting in shorter air ducts.
- Replacing materials with similar products, but with lower thermal conductivity, only lowered the specific space heat demand with 0,5kWh/m^2/a.
- To reach Passivhaus standard it was also necessary to increase floor slab insulation with 50mm extra and 100mm extra insulation in the roof, which lowered the specific space heat demand with respectively 0,5kWh/m^2/a and 1,8kWh/m^2/a.

The results on lowering the specific space heat demand can be seen in figure 5 below, which shows the effect of the improvements listed above.

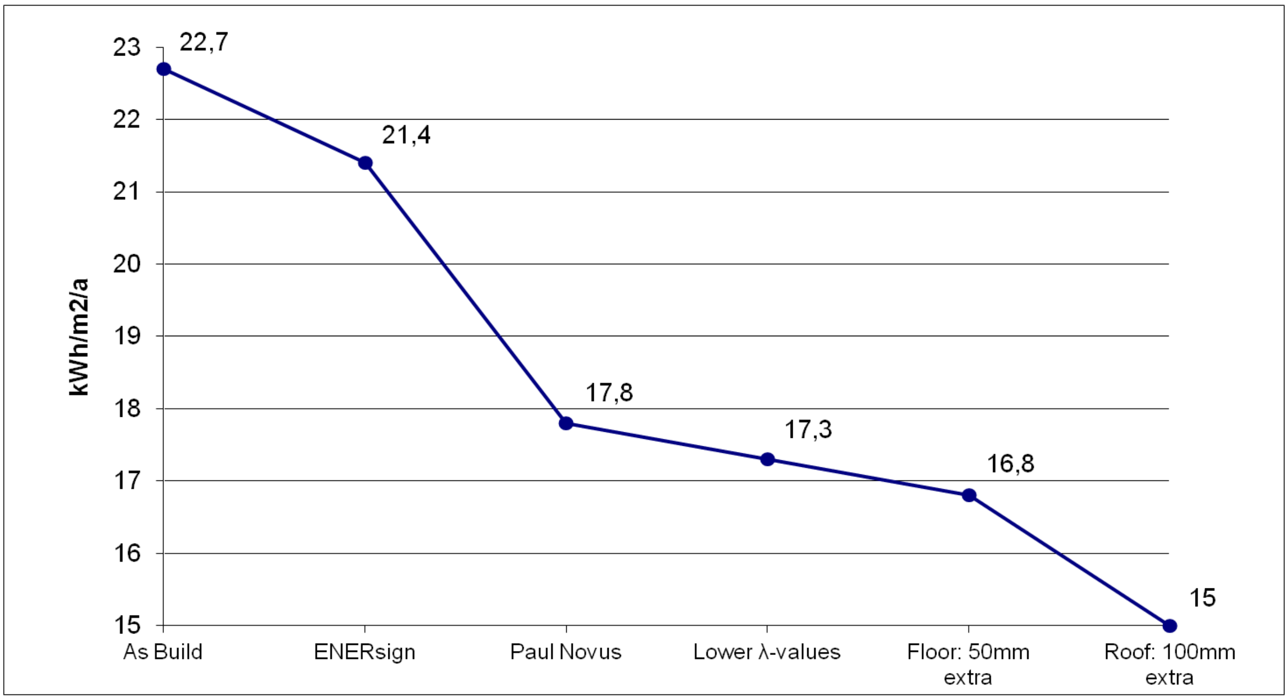

Figure 5 The effect of the listed improvements on the specific space heat demand.

Other possible improvements were to remove the roof lights or minimize the area of the building envelope, for example by lowering and retracting the entranceway. As mentioned above the roof lights had a negative energy balance, but removing them would only lower the specific space heat demand with 0,4kWh/m^2/a and at the same time lower the daylight levels considerably, which would consequently increase the needed energy for extra electrical lighting.

Figure 6 Higher ceiling height of the entranceway.

By lowering and retract the entranceway the building envelope would be minimized by 62,4m^2, which would lower the specific heat demand with 2,1kWh/m^2/a. Although this is a considerable reduction, by doing this the architectural expression would be drastically changed, as there would no longer be a clear emphasis of the entranceway and the interior spatial connection to the stairs and higher floor level of the adjacent building towards south would be lost. Because of their impact on the architecture, these "improvements" were not implemented.

Conclusion and discussion

The calculations and results above shows that the answer to the initial question is 'yes' it is possible to meet the Passivhaus requirements with a north facing building with almost no passive solar gains. To do so, we have to implement a new energy design strategy for this specific project. This strategy prioritizes the needed improvements with regard to their energy saving potential and the wish to minimize impact on the architectural expression. When these aspects are taken into consideration the new energy design strategy for the administration building of Blaakilde Boarding School prioritize to first:

1) Minimize ventilation heat losses.
2) Minimize window heat losses.
3) Use insulation materials with lower thermal conductivity.
4) Fill out void in floor slab with 50mm extra insulation.
5) Increase roof construction with 100mm extra insulation.

These improvements could be done almost without any impact on the architectural expression (the 100mm extra insulation in the roof although means equally lower window height). In the strategy above the economic costs of the listed improvements have not been taken into consideration. A following cost benefit analysis remarkably showed that the improvement with highest energy potential, the ventilation heat losses, also turned out to have the lowest additional costs, as the costs of the *Paul Novus* unit almost equals the used ventilation unit. Likewise the use of insulation materials with lower thermal conductivity would only be slightly more expensive. The use of extra added insulation meant a considerable cost increase, especially in the roof construction, as this would require additional lathing as well. The most expensive energy improvement would although be the use of the Passivhaus certified *Pazen ENERsign* windows, as the costs of the windows would be about twice the costs of the used *Ecliptica* windows.

With a 45% reduction of the ventilation heat losses at almost similar costs one might ask why the Genvex unit was chosen. The HVAC mechanic was chosen by the general contractor. As the chosen mechanic had no prior experience in working with Paul ventilation units, this would nonetheless have increased the costs compared to the Genvex unit. Furthermore Genvex is a local manufacturer, which provided better possibilities of after sale service and the required periodic maintenance. This although shows the importance of giving the designing architects, engineers and technicians influence on the choice of subcontractors, as there is a great energy saving potential by using professionals with experience in and know-how of both local and international products.

If the economic costs of the energy improvements are taken into consideration, the new energy design strategy would therefore look the same as above, although with one larger exemption. Minimizing the window heat losses by using the certified Passivhaus windows would drop from the second priority to fifth and last priority, as it is by far the most expensive improvement. In total the additional costs of all the needed energy improvements to meet the Passivhaus requirements would be approximately an extra 6 % of the total construction costs. A simplified life cycle cost calculation showed that this investment would not be profitable as the repayment time would be too long. The calculation was based on the life expectancy of the building components and the annual energy costs savings, in regards to the needed investment. This means the energy improvements are profitable, if:

$$\frac{life\ expectancy \times annual\ cost\ savings}{investment} > 1{,}33$$

The factor of 1,33 is set as a minimum to take the investment interest rate into consideration [LCC]. With a life expectancy of 30 years, annual cost savings about 1.350DKK and total investment of 143.300DKK, the resulting profitable factor would only be 0,28. Even if the investment rates are not taking into consideration, the break-even point for the energy improvements to be profitable will be 107 years. It would therefore not be advisable to implement the additional energy improvements, as the energy demand of the build project is already low and further reductions would be minimal, but costly.

We believe the experiences and results of the analyses and calculations above will be of interests for others who work with challenging the possibilities of meeting the Passivhaus criteria within far from optimal Passivhaus conditions.

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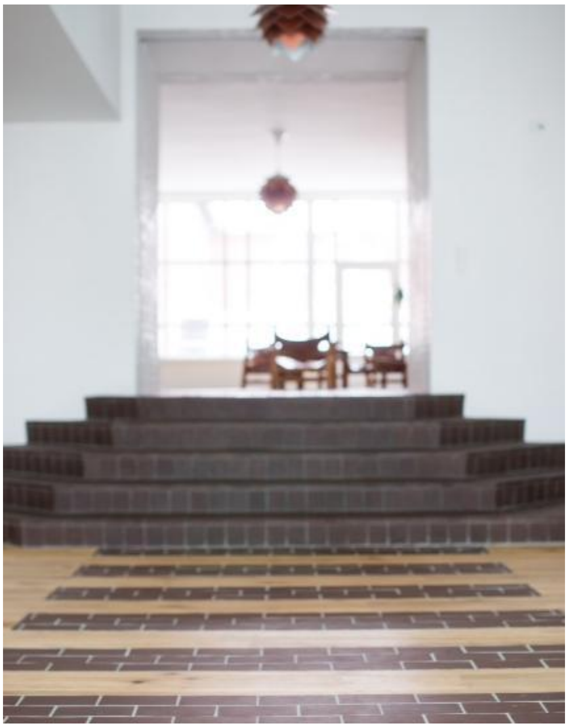

Figure 7 Entranceway.

Figure 8 Glazed north façade.