105: Innovative solutions in passive house details

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Abstract

For the realization of the first passive house demonstration projects in Belgium, passive houses were requested by convinced clients, designed by architects with experience in low energy building, and built by contractors with a feeling for working in building teams. These first passive house examples were not limited to one specific building system, but already showed a diversity in technical solutions.
Due to networking initiatives and financial stimuli, the demand for passive houses has grown exponentially in Belgium, like in other European countries. Nowadays, clients base their decisions on available grants and tax reductions, any architect is consulted for building a passive house and many contractors still lack experience and practical information.
The Presti 5 research project ‘Details in the passive house standard’ acknowledged this lack of practical information. Its goal is to multiply the realization of good construction solutions to assure the quality of construction of further passive houses. This is done by defining and spreading practical design outcomes for the Belgian building situation, providing both design and construction information.
In collaboration with the building industry and knowledge institutes, building details are designed and established for both massive and wood construction of passive houses, linking the innovative construction techniques of a passive house to the Belgian building tradition. Working groups were formed that discussed these details on a regular basis. Thus, in the scope of less than one year more than 10 fundamental building details have been finalized, in agreement with building industry and knowledge institutes.
This paper gives an overview of the existing innovative solutions in Belgian passive house construction, discusses experiences and the potential of the related research process, and discusses examples of construction details in passive house standard, with specific concern for the thermal quality and air tightness.
The building details will shortly be spread to all Flemish architects in order to multiply the local knowledge on passive house construction. It is recognized that with the current state of the building market, good building details are essential for the broad introduction of passive houses. Finally further research ideas are discussed.

Keywords: construction details, building element connections, building elements, passive house standard, passivhaus

1. Introduction

When Passiefhuis Platform vzw (PHP) was founded in 2002, the number of people who knew about the passive house concept could be counted on two hands. The every day building practice hadn’t changed much since the seventies when the oil crises introduced insulation into the traditional cavity wall construction.
Belgium has a moderate maritime climate as a whole, but you can find some differences between the regions. The average temperature is lowest in January at 3°C (37°F), and highest in July at 18 C (64°F). The average precipitation per month varies between 54 millimetres in February or April, to 78 millimetres in July.
The minimum design temperature for winter is defined by the Belgian standard NBN B 62-003 ‘Calculation of heat losses of buildings’ (1986) and varies according to the region from -7°C (maritime climate) to -12°C (worst case modified continental climate) and according to the height above sea level. According to this standard the designer can lower this temperature 4 to 6 K for buildings with an exceptional comfort level.
The maximum design temperature is not standardized and is usually taken as 30°C for summer conditions – above this outside temperature HVAC providers usually do not give comfort guarantees.
On average, 4 to 6 centimetres of thermal insulation are applied in standard building practice in Belgium, much less than in other European countries. On an academic level, thermal bridge free construction and wind tightness are addressed, and on the architect’s plans the insulation layer is an integrated part of the wall construction, but on the building sites the quality of the installation of insulation is hard to assess, hidden by the façade that is sometimes still erected together with the insulation. Also the small amount of insulation used means a high level of error tolerance. Applying more ambitious levels of insulation requires solutions for the

increased impact of thermal bridges, wind and air tightness, and ventilation.

At the start of the new millennium, a select group of motivated professionals, with experience in low energy building, saw the potential in promoting passive house construction, as it was based on a well defined, scientific and quantitative definition. The passive house could become the spearhead for introducing the passive house building concepts and components in the Belgian market.

The challenges in building passive houses were not of a complex technical nature in itself. Designing and calculating a passive house does not require highly trained engineers to calculate, adapted spread sheets are sufficient (e.g. the Passive House Planning Package, PHPP), allowing the architect to calculate the passive house from an early stage in the design process.

The big challenge lay in changing the design and construction process towards an integrative approach. Traditionally building a house was a fragmented process where every party (architect, engineer, contractor, subcontractors, …) worked on his own separated field of expertise. The architect designed the building and lay out the principles of construction, the contractor then implemented them into ad hoc solutions. For standard constructions, this worked because of a common knowledge and understanding of standard solutions.

For building passive houses, this layered approach of construction was not applicable. First of all, there was no common basis of knowledge between the different players. Secondly, the impact of a non integrative design on cost efficiency would be very negative.

For example, not introducing good solutions during the design process to assure airtight construction, would force the (sub)contractor into improvised on site solutions, which would be inefficient and short lived.

The motivated parties of the first Belgian passive houses needed to overcome both challenges. The required minimum of thirty centimetres of insulation in these designs, was quite far away from every day standard. In traditional cavity wall construction 8cm of insulation was considered ambitious. Only in timber frame construction, 14cm of insulation was sort of every day practice. Exterior wall insulation, covered in plaster, was and still is rarely used in Belgium. For this reason, most of the first passive houses in Belgium used a timber frame construction.

The first certified passive house in Belgium, designed by denc!-studio, reflected this trend (Fig. 1). To connect to the existing building experience, and to incorporate easy solutions for thermal bridge free and airtight construction, the architects came up with an intelligent and innovative solution: the exterior walls of this terraced house were erected out of a traditional 14cm thick timber frame construction on the inside and a 9cm thick timber frame construction on the outside, sandwiching a 10cm wide continuous layer of insulation. The side walls of the terraced house were load bearing, and the wind and air tightness was assured by a PE foil inside and out.

Fig 1. Certified passive house, Heusden-Destelbergen, architect: denc!-studio. The façades are constructed out of two standard timber frame constructions with a continuous layer of mineral wool insulation in between

All first passive house examples in Belgium showed this trend to find innovative solutions, on the crossroads between high insulation and air tightness requirements and existing building tradition.

The passive house in Deinze (Fig. 2) in it's form reflected a traditional farm house. Because of the passive thermal comfort inside, the architect opted to unify the whole interior into one big space, leaving not a single inner wall to support the structure. The solution asked for an innovative construction combining brick walls, a concrete girder and steel trusses. Except for the thermal insulating bricks at the bottom of the walls, this construction could as well have been part of a traditional house. The insulation layer was added on the outside as a non load bearing TJI construction, filled with mineral wool.

Fig 2. House using passive components, Deinze, architect: denc!-studio. The house is built as a shell with a total free interior. The lack of inner walls stabilising the construction calls for a rigid mix of brick, concrete and steel, around which a non load bearing construction out of TJI beams supports the mineral wool insulation.

The certified passive office building for the port authorities of Ghent (Fig 3) was the first large scale passive building in Belgium. The architect evr-architecten had good experience in low energy buildings, but needed to design a building that would be built by a large building firm. They combined a standard concrete slab construction

Fig 3. Certified passive office building, Ghent, architect: evr-architecten. This office building uses a traditional concrete floor slab construction, providing the necessary thermal inertia. The façade around it is a highly insulated timber frame construction, built on site.

with a passive façade. This façade, though originally planned to be prefabricated, in the end was built on site as a classical wood frame construction. To ensure a good build quality, special measures were taken. For example, to train the builders in air tightness techniques, a small section of the wall was finished long before the rest and used as a model. Communicating the global goal to all workers, meant that each of them saw the bigger picture.

2. The Presti 5 project "construction details in passive standard"

2.1. The need for good details

The first passive houses built in Belgium were designed and constructed by motivated early adaptors, who valued innovation over short term cost efficiency.

Today, the passive house development in Belgium has entered the next phase: the idea has found an early majority. The continuous attention for energy questions in the media sparks a growing awareness amongst people. This has sparked a broadened interest in passive building, amongst media to communicate about them, and amongst future house owners to start planning their own passive house.

Grants and subsidies on national and local levels for passive construction have an impact on the market. On a federal level in Belgium tax reduction for the construction of passive houses offers a substantial benefit. The government has also announced to finance the construction of 25 school buildings in passive house standard, to serve as test cases and examples for future school construction. Also, budgets have been allocated for social housing in the passive house standard.

This illustrates that passive construction in Belgium is by far no longer limited to motivated builders of single family houses, but starts to find a broad application in the broader market, including public and service buildings, and even renovations.

This fast growing interest puts pressure on the market. The forerunner architects and contractors are overwhelmed with demands for new projects, so a second wave of newly interested parties comes into play: a rapidly increasing numbers of architects, engineers, contractors, workers, producers, technical services companies, etc. all come into contact with the passive house concept for the first time, and all are being faced by the same challenges as the forerunners did.

So the need for easily accessible high quality information is very high. Typical questions that need to be answered are:

- How can air tightness be realised in an efficient way?
- How do you solve constructive thermal bridges?
- What strategies are used for incorporating those thick layers of insulation into the wall?

But the need for good information is not limited to the direct professionals. Future house owners, technical schools, government officials, decision makers, … all have questions about how this passive house standard is realised in practice.

2.2. Goals of the project

A project "construction details in passive standard" was started, with the support of the Flemish Region, in the framework of the Presti-5 programme. The Presti-5 programme, an acronym for PREvention STImulation, supported by the Flemish Region, aimes at reducing emissions through stimulating preventive measures.

PHP argumented that to prevent emission of CO_2 in the residential sector, stimulating the construction of passive houses would result in a reduction of emissions by 80% per building, compared to the current construction standard. Compared to the existing building stock, the gain is even higher. Stimulating the passive house concept by promotion and spreading construction details is nowadays seen as an obvious way of prevention of energy and thus CO_2 waste. So the passive house standard developed by Wolfgang Feist and collaborators was taken as a starting point for research. According to the European vision (defined in Promotion of European Passive Houses), the standard defines a building envelope to provide good indoor thermal comfort with:

- An annual maximum heating and cooling demand requirement ≤ 15 $kWh/m^2.a$ (residential surface area)
- An annual maximum primary energy input for all services (heating, ventilation, warm water supply, domestic electricity) of ≤ 120 $kWh/m^2.a$

The main goals of the project were to:

- Design good quality construction details for passive houses in the Flanders Region
- Spread these details among a large group of professionals in the Flanders Region

- o Create highly valued reference information for Dutch speaking architects and information material for their clients
- o Transfer knowledge to planners and building contractors on the threshold of building passive houses

At the time of the start of the project in 2007 only one Austrian reference was available for design of passive house construction details (development of the IBO Passivhaus Bauteilkatalog), specifically addressing Austrian building methods. In the Hanover Region some experiments were undertaken to promote passive house details for renovation through a regional web site. Some German companies offered only product specific passive house details, addressing the German building practice. Several references (mainly in German) were available on the design of passive houses, but these only addressed general principles and German construction methods.

2.3. Choice of construction types

The specific choice of construction types was based on building experience in Belgium on the one hand and relevance to the building tradition on the other hand. From the start of the project, the choice was made to choose a timber frame construction as well as a massive construction.

Using FJI-beams as the standard building element was and is something often used in Belgian passive houses, not only in floors and roofs, but also in the walls. For this system, some years ago building details had already been designed with a multidisciplinary team as part of a innovation study to use FJI-beams for wall construction. Now, three years later, these details could be re-evaluated, based on real life experience. To match the Belgian, often obligatory, building style, a brick façade was chosen.

As for the massive construction, the choice was more difficult. On one hand a passive version of the traditional cavity wall would have a very large impact on the building scene. But there was no experience at all with introducing very large amounts of insulation into a traditional cavity wall, and also the thickness of the walls was to be questioned. So the choice was made for an outside insulation with plaster, attached to a massive brick construction.

2.4. Choice of details

Next, a set of typical construction element connections was chosen for each system. This selection was smaller than to fully document a typical construction system, as we were limited in time, but still broad enough to be able to highlight all key elements. The following connections were chosen:

- o Foundation slab and façade wall
- o Foundation slab and door
- o Window and façade wall in horizontal and vertical section
- o Façade wall and flat roof
- o Façade wall and tilted roof

For wood construction, the junction between a floor slab and a façade wall was added, and this for both a platform and a balloon frame method. For massive construction, it was chosen to look at the connection between the side of a tilted roof and an outer wall.

2.5. Two working groups

Two working groups, one for each construction system, were assembled. The participants spanned the whole scale of professionals, each with their own experience: architects, contractors, insulation producers, building material producers, knowledge institutes, …

Work in both working groups started with an overview of experiences, followed by regular meetings, roughly once a month, to fully discuss developed details, each time changing focus between different key elements, like for example the thermal performance of the connections, the building practice, air tightness techniques, used materials, …

The working groups quickly also became knowledge pools for dissemination. For new, interested parties, participation in a working group was also a forum to meet with experienced players. Examples of this were an architect faced with a first passive design, as well as a construction company developing a prefabricated passive house for the private housing market.

2.6. Attention to building practice

The goals of the project, design good quality construction details, aimed at a large professional audience, were broadened throughout the project. Through debate in the working groups, it quickly became clear that there was a large need for good information about the every day building practices. The details should not only focus on the principles of design, but elaborate specific examples of implementation. These specific solutions illustrate the possibilities of creative design, and their impact on efficiency.

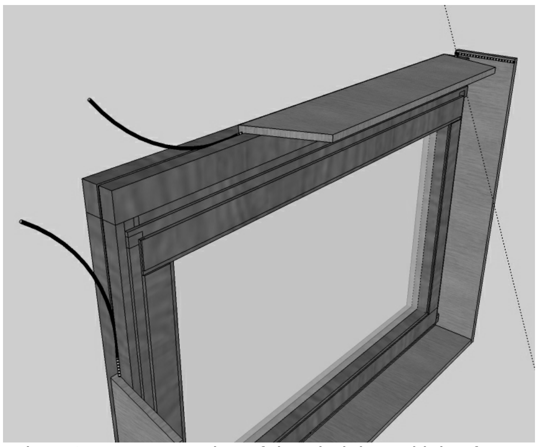

Fig 4. 3D representation of the air tight multiplex frame installed around the window

As an example (see Fig. 4), the windows are proposed to be first incorporated into an air tight wooden frame, before installation into the wall. This is far from the only solution, but it illustrates how a simple choice during the design process can dramatically increase efficiency and ease of assuring air tightness of the whole. Instead of having to span the gap between window frame and inside air tightness layer of the wall, only bridging of frame and wall is required.

The building details are not limited to a single drawing, sketching the design principles, but include a detailed description of how the construction is actually built, both through an assembly plan as through a text, highlighting the reason for the specific measures and their interaction in the greater whole. An illustration of this is shown in Figure 5. This approach was mainly inspired by the magazine Holzbau, where regularly passive house details are described.

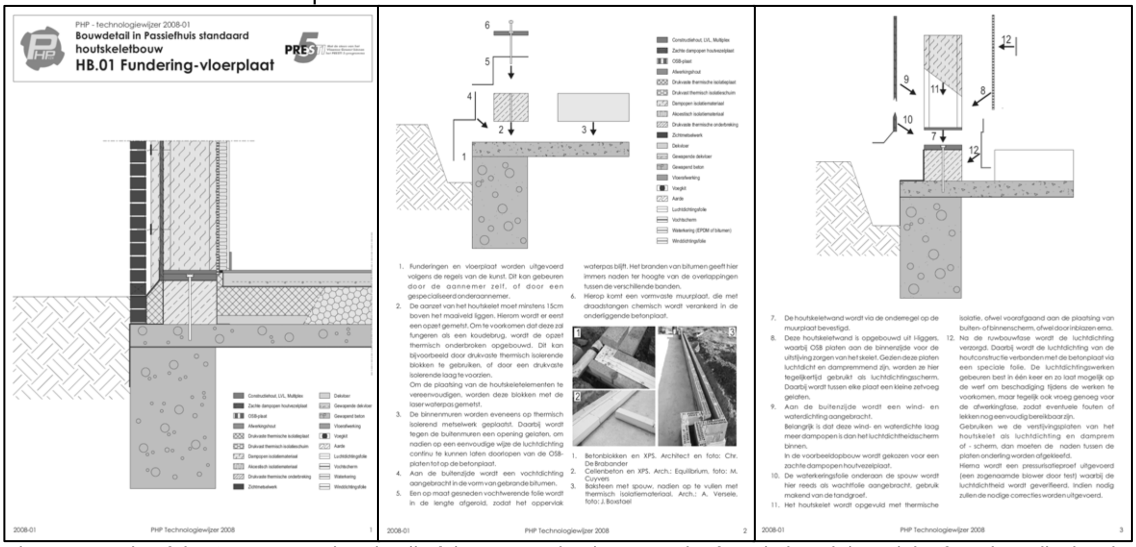

Fig 5. Example of the 2D construction detail of the connection between the foundation slab and the façade wall, showing the detail itself, a legend, an assembly plan and text, and some photos of real life examples.

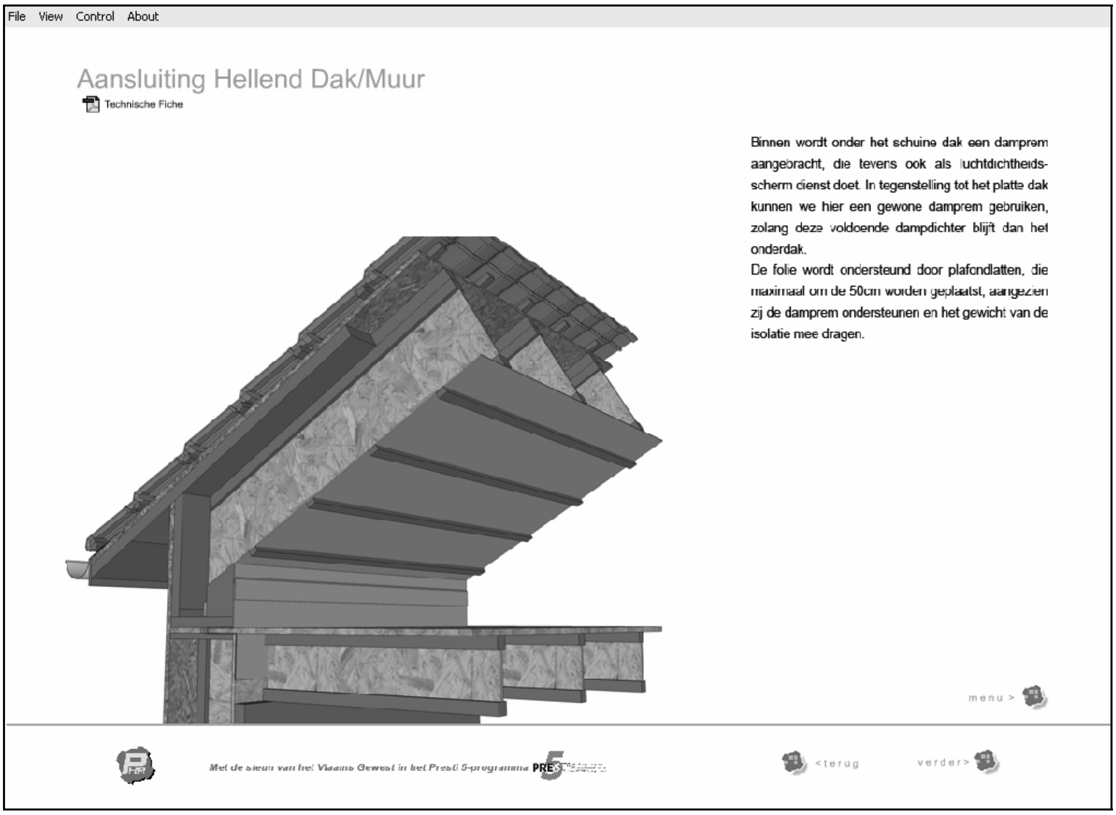

Fig 6. Example of the 3D detail web component of the connection between a façade and a tilted roof, with an explanation about this specific step at the right, and the navigation tools to scroll through the different steps at the bottom.

2.7. The deliverables

The second way the original goal was broadened, was by rethinking the original format into a more visual and accessible one. The two dimensional drawings of the construction details, together with their assembly plans, explanations and real life illustrations, being more abstract in form, are aimed more at architects and engineers.

To lower the threshold, three dimensional details were developed as a web component, incorporated into the website of Passiefhuis Platform (www.passiefhuisplatform.be) and directly accessible via the link www.bouwdetails.be.
The assembly plan was translated into a step by step 3D build up of the construction element, each step being accompanied by an explanation just as in the 2D construction details, as illustrated in Figure 6.

The target group of this web site clearly surpasses just the architects, engineers or contractors, and reaches out towards every party that comes into contact with the passive house concept, through advise, education, grants, profession or personal interest.
Technical schools can incorporate this into their lessons, government and non government organisations can use this as an internal or external visualisation of the sometimes abstract passive house concept, and so on…

3. Further research

Due to the success of this research, now finished, further initiatives are planned together with building companies to evaluate and promote specific passive house details. For instance the working group considered lost casing systems also to be a promising alternative, as well as other more 'traditional' constructions.
Some companies have expressed interest to continue participation. Also system builders are interested to have their construction evaluated by independent experts.
Especially considering renovation good construction details, both for architects and for do-it-yourself construction, can also be a very important resource.
Meanwhile PHP continues some of this research through support of the Flemish Government, within a project of technological service provision for small and medium enterprises, focusing on innovative building shells.

4. Conclusion

The broad introduction of the passive house standard into a regional and traditional market creates an ever increasing demand for technical information, spanning the gap between every day building practices and the passive house standard. Contrary to traditional construction, there is no common knowledge base connecting the different parties, so building teams and commissioning become very important.
Adaptation to local building traditions helps to reduce the gap between tradition and passive house construction. This has a positive effect on the supply and on the demand side.

5. Acknowledgement

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6. References

1. Mlecnik, E. (2008), Marketing of Passive Houses: Experiences from the Low Countries. In *Passivhus Norden 2008*. Trondheim, Norway, April 2-3: p. 192-201.
2. PEP (2008), Promotion of European Passive Houses, Intelligent Energy Europe SAVE project, [Online], Available: http://www.europeanpassivehouses.org
3. PHP (2008), Project files and papers Passiefhuis-Platform vzw, [Online], Available: http://www.passiefhuisplatform.be
4. PHP (2008), Building details passive houses Passiefhuis-Platform vzw, [Online September 2008], Available: http://www.bouwdetails.be
5. proKlima (2008), http://www.baudetails.info/
6. Mlecnik, E., Marrecau, C. (2008), Passive House Projects in Belgium. In *Int. J. Environmental Technology and Management*. Accepted for publication.
5. Mlecnik, E. (2007), PassiveHouse 2007: experiences with five years of promotion of passive houses in Belgium. In *PassiveHouse 2007*. Brussels, Belgium, September 7: p. 29-40.
6. Versele, A., Van Loon, S., Mlecnik, E., Klein, R., Wauman, B. (2007), Contracting for Building Teams and Passive House certification in Belgium. IEA ECBCS Annex 47 working document A47-A-M5-B-KAHOSL.
7. Waltjen, T. (2005), IBO Passivhaus Bauteilkatalog – a catalogue of building elements specified for Passivhaus standard. In *10DBMC International Conference on Durability of Building Materials and Components*. Lyon, France, April 17-20.
8. Fachverlag Holz (2006-2008), Holzbau, die neue quadriga (several magazine issues illustrate passive house details).
9. Kaufmann, B., Feist, W. (2004), Passivhäuser erfolgreich planen und bauen: ein leitfaden zur qualitätssicherung. Fachbuch F12 ILS Aachen.
10. Schild, K., Weyers, M. (2003), Handbuch Fassadendämmsysteme: grundlagen, produkte, details. Fraunhofer IRB Verlag.
11. RAL (2006), Leitfaden zur Planung und Ausführung der Montage von Fenstern und Haustüren. RAL-Gütegemeinschaft Fenster und Haustüren e.V., Frankfurt, Germany.
12. Passivhaus Institut Darmstadt (2007), PHPP 2007 (Passivhaus Projektierung-Paket), software for the evaluation of passive houses, www.passiv.de, Dutch version available from www.passiefhuisplatform.be