Passive House Sports Hall Sande - Exemplary Building on Sand?

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1 Introduction

The city of Paderborn, with its own company for building management GMP, wants to sustainably reduce the consumption of energy and resources in the building sector and prepare the broad introduction of passive house technology by means of a pilot project. For this purpose, the upcoming new construction of a double sports hall in the Sande district was selected in 2009, for which two recently constructed reference buildings in improved EnEV standard exist. With a comparable budget, the heating requirement is to be halved again, a cooling requirement avoided and passive house standard achieved. To develop a sustainable solution, the city called in the author's consulting office.

Figure 1: Architecture

Based on the existing architectural concept, characteristic features of the comparable buildings (such as hall/adjoining room geometry, curtain wall, lighting via skylights) were to be retained on the one hand, and local boundary conditions (preservation of newly planted shade-providing trees on the south side of the hall and building on sand) were to be taken into account on the other. The sandy soil implied a foundation with a high thermal bridge, for which cost-effective insulation solutions had to be found within the framework of the passive house approach - possibly in trade-off with other components.

The Passive House Standard is based on the relevant requirements for sports halls [Kah2009]. As a central assessment criterion and compass for economic efficiency, the net present value over the service life is used, which can also be used as an instrument for sustainable optimisation of measures [Steinmüller2008]. User equity and comfort of use form the core of the social criteria, energy efficiency and openness for renewables the core of the ecological criteria.

In the solution process, the critical building parameters for the winter and summer case, including their relevant sensitivities, are first identified, and the given initial case is transformed into a Passive House-compatible base case, which in turn is refined and optimised in an iterative process. For quality assurance, a certification process is carried out according to the guidelines of the Passive House Institute [Feist 2009].

2 Optimisation of the building envelope

Envelope surfaces are thermal loss surfaces and cost investment, so they should be kept as "compact" as possible from an economic and energetic point of view. Since the building geometry in this project is largely predefined, the optimisation of surfaces was only possible to a limited extent. The optimisation focuses on the floor finish, façade and roof construction as well as skylights, windows, thermal bridges and air tightness.

Ground closure and foundation

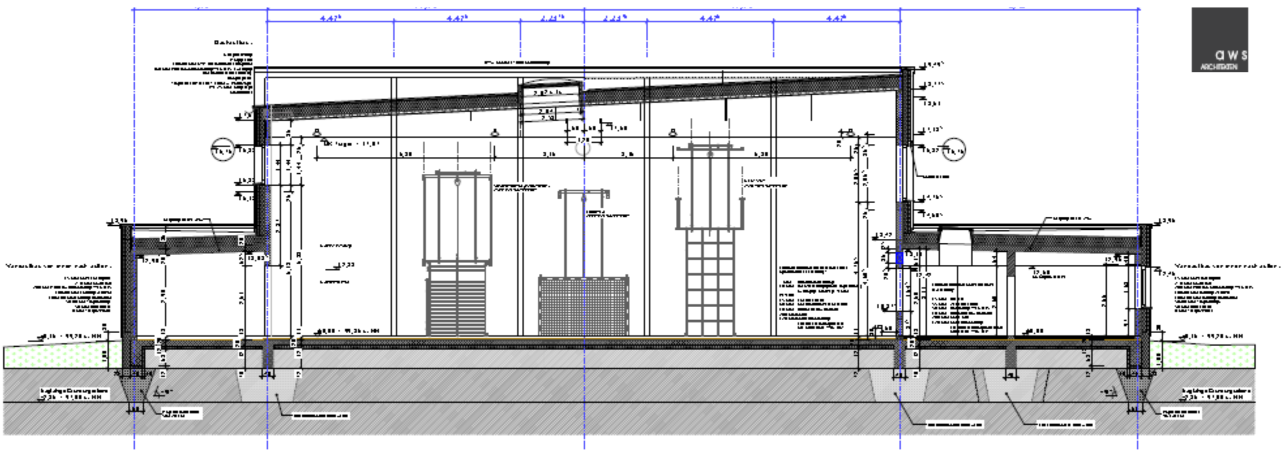

Figure 2: Cross-section of building envelope with foundation

Analogous to the comparative buildings, a shallow-founded floor slab was initially used as the floor finish, with insulation placed under the floor slab and raised to about 20cm to avoid thermal bridges. However, the structural analysis showed that a deep foundation was necessary, which resulted in a "concrete mountain" with 5 "mountain ridges" (strip foundations) and over 20 "peaks" (well foundations) under the floor slab. Extensive insulation of the mountain range would cost a high five-figure figure, so consideration was given to how to limit the costs without calling the Passive House concept into question.

It was considered to insert a compression-resistant insulation layer between the well and strip foundations in order to reduce the "rock" and with it the insulation costs and heat losses. However, rough calculations showed that even this type of rock would result in considerable additional costs and heat losses, and the availability of appropriately pressure-resistant insulation material was also in question.

As a radical alternative, the complete abandonment of the floor slab insulation was proposed. This would save not only the insulation of the "ridges" but also the insulation costs for approx. 1500m2 of floor area, i.e. a total of around €50,000, which could then be invested in much more cost-effective edge insulation and compensatory measures in the rest of the building envelope using the insulating effect of the sand.

recalculation showed that this alternative concept was indeed the most cost-effective variant and that only a small part of the cost savings would be needed for compensatory measures. Despite fundamental support, however, the client and architect pleaded for a less radical implementation with minimal insulation as a "safety cushion". It turned out to be a golden bridge that even with a thin insulation layer under the floor slab, the cleanliness layer could be dispensed with to reduce costs. In the realised variant, an insulation layer reduced to 12 cm was therefore laid in the flat areas of the floor slab, leaving out the "foundation rock", so that the savings mentioned above could be realised, although not fully, but a good half.

Facade and roof construction


Figure 3: Façade construction

Aluminium substructures are often used for curtain walls, which in the present case would have increased the envelope characteristic value by 20 % and the NPV of the energy consumption by over 20,000 € due to thermal bridging. Wooden substructures and, more recently, optimised metal suspensions are available as alternatives with low thermal bridging. The former are tried and tested and can be handled flexibly, so they were chosen. With 28cm mineral wool insulation WLG035, U-values of 0.13 W/m2K are achieved, which are reduced to 0.1 W/m2K at the front ends of the hall by the internal 8cm insulated baffle wall construction. In the roof, the classic Kalzip construction was replaced by an improved, almost thermal-bridge-free wood-supported variant, which achieves a U-value of 0.11 W/m2K with 36 cm WLG035 mineral fibre insulation.

Dome lights, windows

Light domes and windows fulfil multiple functions with lighting, solar heat utilisation, ventilation, smoke extraction and insulation, so that several requirements have to be weighed up against each other and optimised.

This applies in particular to the skylight domes, which are not without their problems in terms of thermal engineering. Here, improved system solutions were sought which, together with the windows, can efficiently perform the above multiple functions. In addition to triple-glazed skylights, 5 and 6 acrylic domes are currently available. Although the U-values of these elements have decreased in recent years, they are still generally above 1 W/m2K, whereby the reference surfaces and built-in thermal bridges to be taken into account are often in need of clarification, so that U-values that are projected onto the opening of the building shell in the same way as windows can turn out to be significantly higher. The g-values are between approx. 30 and 55%, the light transmission between 40 and 70%.

Figure 4: Light domes, light

The shortlist initially included 5-fold skylight domes with U_g = 0.7 W/m2K, g = 52%, 10cm thick insulated edge and a U-value of approx. 1.1 W/m2K when installed. Finally, 6-fold acrylic domes with U_g = 1 W/m2K, g = 34% and 15cm thick insulated edge were available, whose U-value when installed is 0.99 W/m2K [Krick 2011]. With this dome, the desired functions can be achieved. However, the technical values and the selection, delivery and verification process indicate that there is further potential for optimisation in this area.

For the windows and vertical glazing, on the other hand, a large number of components suitable for passive houses can be used. Fixed glazing with a low proportion of frames (average 20%) is largely used in the upper hall area, while movable window elements and doors are used in the changing room and entrance area. The U-values are between 0.7 and 0.8 W/m2K, the g-values are 48% (clear) and 44% (matt).

Air tightness and residual thermal bridges

According to the Passive House Standard, an n50 value of 0.6 h-1 is to be achieved, which is reflected in the heat balance with a good 3 kWh/m2a or 20% of the heating limit value. The A/V ratio of 42% signals reduction potentials of a factor of 3 compared to single-family houses, so that 0.2 h-1 should be aimed for as an adequate hall-related limit value and 0.1 h-1 as a target value. In fact, a value of 0.13 h-1 was measured shortly before completion (with significant leakage from doors that still needed adjustment). The air tightness of the hall is therefore more than a factor of 4 below the current passive house requirements and more than a factor of 10 below the EnEV requirements.

Where possible, thermal bridges were avoided by design or greatly reduced by appropriate measures. In total, they contribute around 10% to the weighted envelope characteristic value, with around 4% being accounted for by the deliberately accepted thermal bridges in the floor slab and 3% each by predominantly wood-related residual thermal bridges in the façade and roof.

3 Building technology and operation

The technical centre is located in the middle of the changing area so that the hall and changing rooms can be supplied with air and heat over short distances.

A highly efficient rotary heat exchanger is used for ventilation, the heat recovery efficiency of which - after adjustment with the PHI - was determined to be 80%. The control is temperature-, humidity- and CO_2-dependent, whereby in summer - with the exception of WC and shower room ventilation - there is a switch to automatic window ventilation that can be influenced by the user.

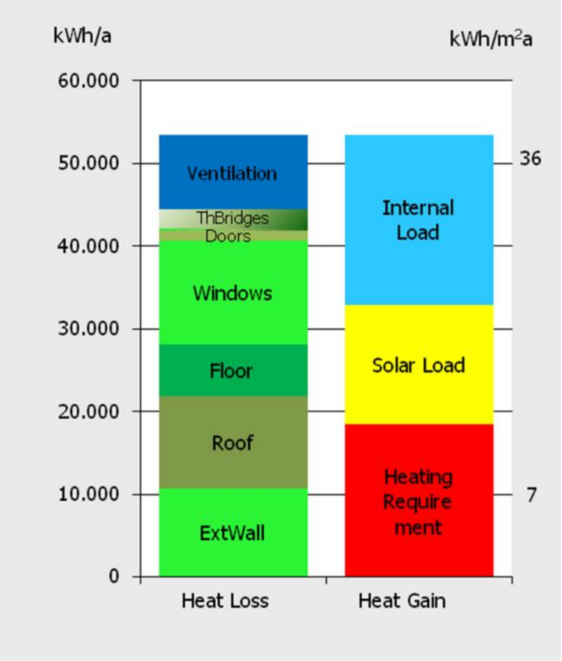

Figure 5:Annual heat balance

The above-mentioned efficiency measures reduce the heat losses to such an extent that about 2/3 of them can be passively covered by free heat and only 1/3 has to be actively supplied with heating energy.

The residual heat supply is provided by condensing boiler technology, which will soon be supplemented by a pre-installed thermal solar system. The ground collector-based "active" cooling system of the comparison building is omitted. Cooling is "passive", with three openable SHEV/light domes and 2 x 4 opposing bottom-hung windows using wind and thermal lift forces for effective day and night ventilation. The southern hall windows can be shaded by adjustable external blinds. In case of insufficient daylight, lighting is provided by automatically dimmable specular louvre luminaires fitted with T8 lamps.

The roof is prepared for photovoltaics to generate renewable electricity.

4 Passive house standard and plus energy

All characteristic values of the Passive House Standard were achieved or, in some cases, significantly undercut. The heating requirement of 13 kWh/m2a is a good 10% below the requirement value, and the primary energy value of 70 kWh/m2a is a good 40% below the requirement value.

Solar thermal energy will reduce the primary energy value by a further 10%. With PV, the entire annual primary energy demand of the building can finally be covered and, in addition, the same amount can be made available again as "plus energy".

5 Conclusions

The advantages of passive house technology were convincingly demonstrated in this project. The foundation on sand did not lead to an increase in insulation costs, despite foundations with high thermal bridging, but rather to savings with an alternative concept suitable for passive houses. In the area of the curtain wall, the usual heat-bridge-prone suspension can be replaced by constructions that are almost free of thermal bridges at only low additional costs. The same applies to the roof. Domelights take on an attractive multiple function, but still hold potential for optimisation. The n50 requirement value for air tightness of 0.6h-1 is easily undercut by a factor in halls. In order to encourage a consistent exploitation of this potential, this fact should be propagated even more strongly - possibly via an A/V-independent, external surface-related target value.

It is much more difficult to achieve excellent energy performance values for sports halls than for other large-volume buildings, as the heat losses are only allocated to the energy reference area of one floor instead of several. A successful test on such an unfavourable building is therefore to be valued more highly than an analogous test on an average municipal building, especially since due to the specifications in the present pilot project a number of optimisation screws could not be used.

The success has prompted the city and the GMP to apply passive house technology in ongoing projects and to make it mandatory for all future municipal new buildings. In addition, passive house technology is also to be used in the comprehensive refurbishment of old buildings and to radiate into the private and commercial sectors through its exemplary effect.

6 Acknowledgement

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