Project report on Parkwohnanlage Nürnberg Bernadottestraße 42 - 48

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1 Fundamentals

The multi-family apartment house at Bernadottestrasse 42 to 48 lies two kilometres southwest of Nürnberg's city centre, in a privileged location in an architecturally high-value neighbourhood that was built at the beginning of the 1960's. The existing building contains 24 flats, of which twelve are three-room, six are two-room, and six are four-room. The refurbishment was carried out while the flats were occupied, which was, due to the significant amount of work involved, a challenging task. The well-designed floor plans were left completely untouched. While enlarging the bathrooms would have been desirable, the cost-benefit factor for such fundamental changes would have been very high and would have required a complete redesign of the floor plans.

Figure 1: Bernadottestraße 42 - 48 before refurbishment: 24 flats

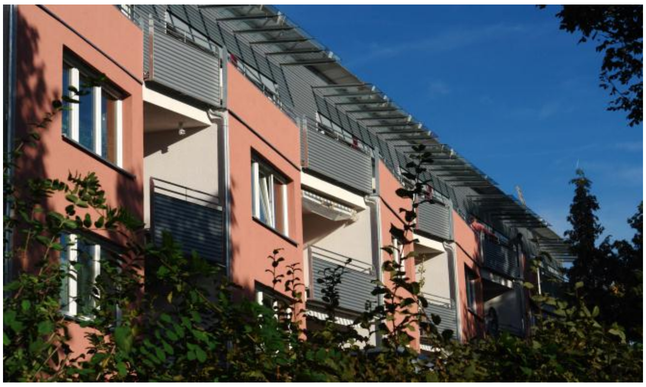

Figure 2: After refurbishment with six additional passive-house flats on the top floor

Initially, the unfinished attic was to be retained, since a purely energy-related refurbishment was planned. Due to the outstanding location however, re-densification of the neighbourhood was discussed, and in the end the addition of another storey within the attic zone was decided on. This slightly increased the eaves height, and the monopitch roof portion was enlarged. In place of the opposite side of the roof on the southwest side of the building, spacious roof terraces were developed. For the six new flats with areas from 70 to 110 m², passive building technology was obviously the best choice of energy standard, since a ventilation system with heat recovery had already been conceived for the rest of the building. So a few centimetres' thickness of insulating layer could be added to the timbers in the attic at very few additional cost. The 24 existing flats in the building have a floor space of 1578 m², and the six new flats in the attic have in total 498 m².

2 Structure

The structure of the existing building represents the usual standards for the 1960's. The exterior walls consist of vertically perforated bricks, while the ceilings are of ferroconcrete. The building has a full cellar.

Components that had already been used in two earlier projects by wbg-Nürnberg at Jean-Paul-Platz and on Ingolstädter Straße, were used as refurbishment technologies. However, the cost-benefit factor had to be improved even further. On the structural side, optimal insulation of the heat-transferring building envelope was required, as well as high-quality windows with triple thermal glazing. With regard to quality assurance, special attention had to be paid to minimising thermal bridges and assuring high air and wind tightness. The structural components are presented in Table 1.

	loval building code in Germany (EnEV) for New Construction	Bernadottestr. Ground floor / 1st Floor / 2nd Floor	Bernadottestr. Third Floor (passive house)
Wall	Insulation 10 cm	20 - 24 cm	30 cm
Roof	16 cm	Roof terrace: 22 cm	44 cm
Cellar ceiling	6 cm	12 - 24 cm	
Windows	U_w = 1,6 W/(m²K)	U_w = 0,92 W/(m²K)	U_w = 0,8 W/(m²K)
Ventilation systems	Window ventilation	Supply / exhaust air with heat recovery	
Mechanical systems		District heating	District heating

Table 1: Passive House components for refurbishment and adding of a storey

2.1 Wall

The vertically perforated brickwork of the existing building is 30 cm thick and the wall had a U-value of 1.1W/(m²K) in the original state. During refurbishment, a compound thermal insulation system with an insulating thickness of 20 to 24 cm was applied. In the loggia some surface areas were insulated with lesser thickness of 12 cm in order to limit the loss of balcony area. Marmorit with Neopor-PS-insulation WLG 035 was chosen as the thermal insulation product. The finishing coat received a scraped-stucco structure with 2 mm granulation. The U-value amounts to 0.16 - 0.14 W/(m²K). The light weight wooden construction walls of the additional storey have a U-value of 0.12 W/(m²K). A curtain wall façade of corrugated aluminium was chosen as cladding.

2.2 Roof

The rafters span over the entire depth of the newly built top storey. This results in a simplification of the static load transfer, so an extremely economical construction could be chosen with a large structural height of the rafters (8/44 cm glue-laminated timber) including an insulating layer thickness of 44 cm mineral wool (λ = 0.035 W/(m²K)). This results in a U-value of 0.09 W/(m²K) for the roof.

The roof terrace lies partly above the living rooms of the flats beneath, and so thermal insulation had to be installed there. In order to limit the construction height, the insulation layer was made as slim as possible: 20 cm with λ = 0.035 W/(m²K). Within this very limited area, the U-value is 0.18 W/(m²K). Above the insulation the sealing foil is placed, which, in accordance with the flat roof code (‘Flachdachrichtlinie’), acts as a water-conducting layer and therefore must be 15 cm below the sealing edge of the terrace doors. A drainage groove reduces the step height outside to five centimetres. Inside the floor structure is elevated, since an additional concrete layer was required above the previously 13 cm thick concrete ceiling in the former roof area. Because of this added layer, the inside height of the exit to the terrace is almost on the same level with the terrace surface.

2.3 Cellar ceiling

Like all floors, the basement ceiling is made of 18 cm thick ferroconcrete. Before refurbishment, the basement height measured 2.28 m high in the corridor area. The insulation height in the corridor area is 24 cm, so that the supply lines for heating and warm water can run inside the warm building envelope. The insulation was blown in and the required structure was built of gypsum board. The U-value amounts to 0.16 W/(m²K).

In the basement compartments, the height was reduced by a step’s height of 24 cm, lowering the room height to 2.04 m. That allowed only 12 cm’s worth of insulation to be installed using rockwool insulation WLG 035. Before refurbishment, the U-value amounted to 1.4 W/(m²K), afterwards U = 0.22 W/(m²K).

2.4 Windows

The existing building had wood-composite windows with Venetian blinds between the panes. In the flats on the ground, first and second floors, plastic windows with a five-chamber profile (U_f = 1.1 - 1.2 W/(m²K)) and triple thermal insulation glazing (U_g = 0.5 W/(m²K)) were installed, with a resulting U_w of 0.9 to 0.95 W/(m²K).

Roller shutters with electric drives were installed at the ground floor windows. The boxes were installed with a 10 cm mounting distance to the wall (rear insulation with WLG 030 insulation to reduce thermal bridging). The lateral guide rails of roller shutters were installed at a distance of three cm from the window frame and the gaps were insulated to reduce thermal bridging. The living room windows on the first and second floors received blinds to to prevent the rooms from overheating in summer. They were installed like the roller shutters above, likewise thermal bridge-optimized and with an electric drive.

On the top floor, passive house-certified Rehau plastic windows were installed. The connection detail in the lightweight wooden wall construction of the top floor walls was installed with five centimetres of extra insulation covering the window frame, in order to reduce thermal bridging as much as possible. To reduce heat gains in summer, blinds were installed on the southwest side.

2.5 Thermal bridges

The thermal bridges were itemized and added up in the course of the energy calculations. Because the passive building method was used, negative thermal bridge loss coefficients resulted throughout the top floor. For the junction details in the basement area, intensive efforts had to be made in order to ensure damage-free constructions, since the existing connections showed high thermal bridge effects. That is why the thermal insulating system on the southwest side was installed all the way down into the soil to the frost line. On the northeast side, the basement ceiling is about one meter above ground, so that running the insulation down to the grade is sufficient. Deeper-reaching perimeter insulation was avoided for reasons of cost.

2.6 Airtightness

Since the building was refurbished while occupied and no extra budget for scientific monitoring before the fact were available, the approach regarding airtightness was very difficult. Blower door tests could not be carried out before the start of construction. Thus, measures in the flats had to be estimated and put out for bid based on visual inspection. In the top floor area, these problems arose only at the connection points. Because it was a new construction, it was possible to develop a consequent air-tightness concept.

Figure 3: Blower door test in a flat

The blower door tests were part of the tender of the general contractor and included reaching an n_{50} value below 0.6 h^{-1}. To start with, separate measurements were made of the individual flats and the top floor flats with the respective technical optimisation of airtightness. Both the external leakages as well as the air leakages between adjacent flats were determined and reduced in this process.

In the existing flats, leakages were found above all in window brackets, empty electrical conduits and electrical boxes and at the entrance doors to the flats. The crucial area however was in the bathrooms, where the old ventilation system with its duct ventilation clearly had more connections to the interior room than the sealed ventilation opening. The newly installed ventilation ducts and heating pipes were very well sealed. Problems however did result in individual places along the ventilation system piping, where individual defects led to leakages.

In the newly built top floor flats the seals were built from scratch. But even then, increased attention was required at the interfaces between the work of different subcontractors which resulted in much rework. Several blower door tests followed by rework were necessary in order to reach the required n_{50} value $\leq 0.6\ ^1/_h$ for each flat under positive pressure.

The final verification of the n_{50} value $\leq 0.6\ ^1/_h$ was done in a stairwell of each house (the separate 'houses' of the building) covering seven to eight flats in each case.

2.7 Ventilation system

During the refurbishment of the Bernadottestrasse project, a central supply and exhaust air system with heat recovery was planned for two houses each. The project engineering was done by Ebök, an engineering company out of Tübingen. The ventilation equipment is located besides the stairway head within the thermal envelope in houses 44 and 46. Each Aerex ventilation unit is designed to provide an air volume of 700 to 1400 m³ per hour for fifteen flats. Each unit has to ventilate 980 m² of floor space. For basic ventilation, an air change rate of 0.35 to 0.4 $^1/_h$ was set, for the higher ventilation stage 0.5 to 0.6 $^1/_h$. The units are controlled in each flat via the air-flow rate. Each tenant has a switch for choosing between the basic ventilation rate and higher ventilation rates.

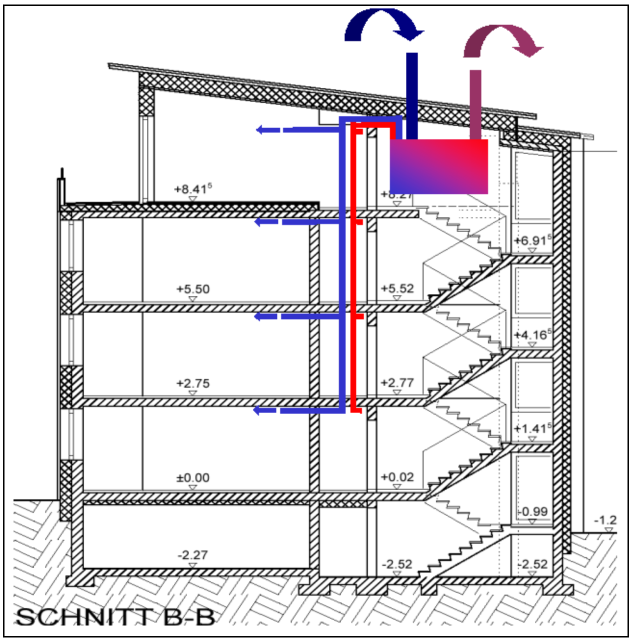

Figure 4: Ventilation plan cross section: ventilation equipment on the top floor

Figure 5: Building services piping under the ceiling of the corridor in the flats

The ventilation pipes within the central area are designed as largely as possible. Fresh air and exhaust air lines run across the roof with their routes through the attic area kept as short as possible, and have high-quality thermal insulation. An effort was made to merge the requirement for good ventilation and large cross-sections with the planners' desire for minimal space requirements for the ventilation system. So it was possible to keep the space needed for the ventilation system for 15 dwellings below 15 m². Frost protection for the heat exchanger in the ventilation equipment is provided by a pre-heater battery installed in the fresh air supply lines downstream from the unit. The heat is provided by the building's central heating system via a small heat exchanger using a glycol-filled secondary cycle.

The distribution lines run horizontally under the top floor ceiling to the ascending pipes. Fire protection in these areas is provided by fire dampers between the respective sections. The vertical lines run in L-90 shafts along the party wall of each house. For flats lying above each other, one pipe each carrying supply or exhaust air was installed. Since the building has two flats per floor, each ascending pipe carries two supply air and two exhaust air pipes in the form of folded spiral-seam tubes with a diameter of 200 mm.

The horizontal distribution in the flats takes place underneath the corridor ceiling. Both supply and exhaust air pipes were installed as folded spiral-seam tubes with diameters of 100 to 125 mm. Downstream from the branch-off from the ascending pipe, there is a maintenance-free fire damper at the shaft transition. This will, however, be inspected regularly to ensure that it continues to function. The height of the suspension should be as low as possible, and it was successfully reduced to approximately 20 cm, depending on traverses, mufflers and drywall construction. Perforations were made by means of core drilling. Long-range nozzles were used as the air-inlet elements for the supply air.

2.8 Space Heating and domestic hot water preparation

District heating supplies heat for heating and domestic hot water. Nürnberg district heating has a primary energy factor of 0.11, and thus provides a heating alternative that is highly efficient and extremely positive ecologically. For the supply to the property a central transfer station for the building was selected, in connection with a dual-pipeline and transfer stations for each flat, which provides individual control of warm water and heating level by the occupants. The piping runs horizontally above the basement corridor inside the newly fitted insulation, and thus lies within the insulated building envelope. The ascending pipes run through each house parallel to the ventilation piping. The distribution throughout the flats likewise takes place in tandem with the ventilation piping inside the suspended ceiling, to the bathroom and/or kitchen, where the transfer station is located. A significant argument in favour of this technology lies in the fact that the devices were mountable to the former connections of the tankless gas water heater without alterations. Since the refurbishment took place while the flats were occupied, the bathrooms were not supposed to be renovated.

2.9 Energy calculations and energy consumption

For the existing building, the energy calculation was made according to EnEV and the Passive House Planning Package (PHPP); for the passive house area on the top floor, verification took place according to PHPP. The results for the existing building and the refurbished building are presented in Table 2.

Calculation according to EnEV (reference surface A_N)					
H_T' before refurbishment	1,40	W/m²K	Q_P before refurbishment	200.8	kWh/(m²a)
$H_T'_{accepted}$ according to actual EnEV*	0,60	W/m²K	$Q_{P\ accepted}$ (EnEV)	89.1	kWh/(m²a)
H_T' after refurbishment	0,25	W/m²K	Q_P after refurbishment	33.6	kWh/(m²a)
Percentage below EnEV	58	%	Percentage below EnEV	62.3	%
Calculation according to PHPP (reference surface A_{EB} / floor space)					
Existing area on ground floor - 1st and 2nd floor (1578 m²)			Passive house area, 6 units, loft (498 m²)		
Previous heat requirement	204	kWh/(m²a)			
Heat requirement post-refurbishment	27	kWh/(m²a)	Heat requirement	15	kWh/(m²a)

Table 2: Energy calculation data according to EnEV and PHPP for Bernadottestrasse 42 - 48 / existing area

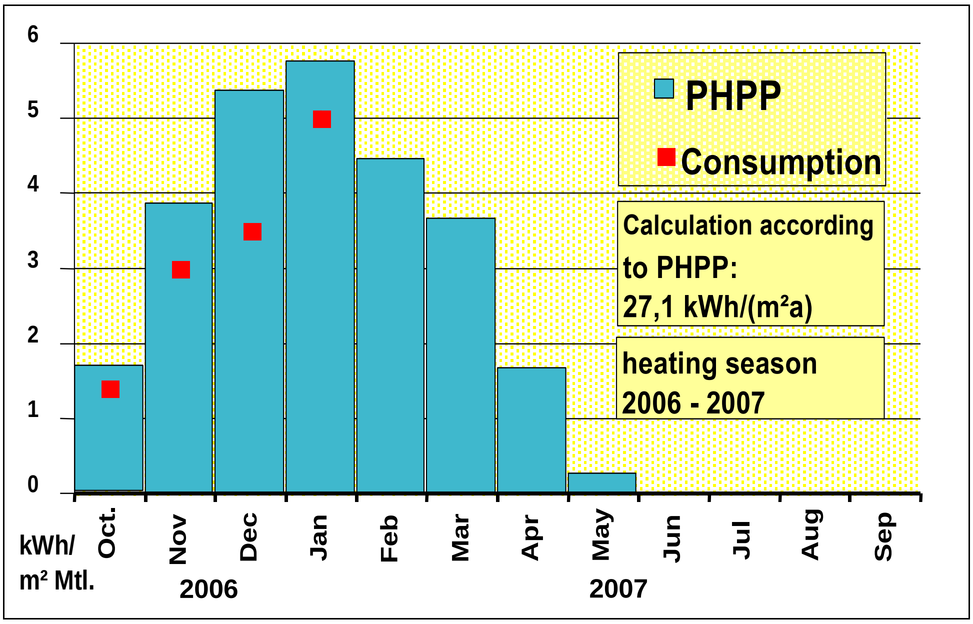

Figure 6: Heat requirement according to PHPP calculation and measured values for the existing flats (as of Feb. 1, 2007)

Consumption is metered monthly at the district heating transfer station. Evaluation of the data (as of Feb.1, 2007, fig. 6) shows that the consumption of heat for heating in existing dwellings lies below the values calculated according to PHPP. A correction by number of heating degree days was, however, not performed.

2.10 Construction costs

Construction costs amounted to approx. € 550/m² of floor space for the existing building (according to DIN 276 cost group 300/400, including VAT.) The costs of the additional storey with six flats built to passive house standard amounts to € 850/m². The extra investments into the passive house technology and into meeting the "EnEV -50% standard", which is 50 % lower energy demand than the actual EnEV reference standard for new buildings, are € 95/m². Modifications made in the interest of historic building preservation created extra costs of € 40/m² of floor space, which must be added to these sums.

3 Conclusions and urban development

The building is located in a residential area with 1030 units that is to be modernized in the coming years. The neighbourhood was built between 1961 and 1964 by wbg Nürnberg, with architect Reichow, on the basis of an urban planning competition. A few days before the refurbishment of Bernadottestrasse 42 - 48 was to begin, the area was declared to have a 'Denkmalcharakter' ('monument character') by the 'Denkmalschutzbehörde' ('monument preservation authorities'). This led to some rushed planning changes in the refurbishment project. The situation was seen as a positive challenge by wbg Nürnberg. Using extensive expert knowledge and skills, and with an emphasis on intensive planning discussions with the administration and the public, an optimal solution for the residential area should be found. The architectural partnership of Fritsch, Knodt & Klug and Schulze Darup & Partner was tasked with producing a master plan for the refurbishment. Essential goals of this planning process are identified as:

- A design in compliance with monument-preservation guidelines and a revaluation of the urban planning situation
- High-quality re-densification in an urban area
- Vitalisation of the area by a balanced housing mix and supporting social measures
- Linking economics and ecology through highly energy-efficient refurbishment in connection with adaptive financing and subsidy models
- Implementing the refurbishment measures within a situation as acceptable as possible to the tenants.

All planners and institutions involved desire that these requirements will be fulfilled as complete as possible and that a win-win situation for all will be achieved.

On the basis of experiences made so far with the refurbished "lighthouse-projects", it makes sense from a technical point of view as well as for reasons of comfort to use passive building technology wide-spread for an entire neighbourhood. The economic framework and the subsidy situation will be among the most critical criteria for determining the energy standard, which is to be specified in the coming months.

Figure 7: Parkwohnanlage with 1030 units: Floor plan typology. (Source: FKK & sd)

Figure 8: Model section for the re-densification of the top floor in cooperation with the monument preservation authority. (Source: FKK & sd.)