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BINE Informationsdienst

Building refurbishment – Gründerzeit houses

Fig. 1

- **Heating energy consumption reduced by over 70%**
- **EnSan building: approx. 20% lower heating energy consumption than standard building**
- **Refurbished beam heads in EnSan building thermally isolated from the exterior wall**
- **Air tightness very difficult to realise in Gründerzeit houses**

The mirror-image building halves before and after refurbishment, left building half: standard building – refurbished according to Hamburg's climate protection programme, right building half: EnSan building

Today, residential buildings from the Gründerzeit are still characterise entire streets, or even districts. These Gründerzeit houses, built between the turn of the century and 1918, are the most characteristic of old inner-city buildings. In many cases, these quarters are now among the most preferred residential locations. Spacious layouts, high ceilings, and the elaborate stucco with which the houses are decorated make them particularly sought-after. This was not always the case. It was once common practice to tear down the Gründerzeit architecture, and to replace it with new buildings. Only in the 1970s could the demolition be stopped, and careful refurbishment of the remaining building fabric began. Today, many of the buildings are protected as listed buildings.
Perimeter block developments of around four to six storeys with richly decorated facades are typical of the Gründerzeit architecture. On the courtyard side, the facade is usually undecorated. Exterior masonry walls which taper from the ground storey to the storeys above are typical. Wooden beam ceilings are found in the upper storeys, and usually steel girder ceilings above the cellar. In some cases, there are bathrooms situated in the flats. The buildings were originally heated by individual stoves. It is not unusual for the heating requirement to be around 300 kWh/m^2 p.a.

In Hamburg, the energy-oriented refurbishment of this building standard has been implemented by way of example, with a Gründerzeit house which consists of two structurally identical building sections. The objective was to realise different refurbishment concepts, so as to compare them in terms of efficiency and costs. The refurbishment occurred according to two standards: one half of the house according to the Hamburg climate protection programme, and the other according to the stipulations of the research field "Enhanced building fabric performance" (EnSan), which is part of the support initiative "Energy-optimised construction" (EnOB). One goal of the refurbishment was to reduce the calculated primary energy consumption of approximately 315 kWh/mÇ p.a. by more than 50%. In this research project, sponsored by the German Federal Ministry of Economics and Technology, special attention was paid to the development of transferable solutions for the refurbishment of Gründerzeit houses. For instance, interior insulation of the front facade and new refurbishment solutions for balconies and beam heads were called for, in order to reduce heat losses and to prevent moisture damage. The work has now been completed. The building is occupied once again, and has been subjected to intensive testing on the basis of measurements.

▶ Initial state

The building, built in 1907, comprises two building sections with identical floor plans, 4 full storeys, and a total of 14 flats and four commercial units. The top floor has been partially upgraded. The front facade, decorated with stucco elements, faces west, and is characterised by the projecting balconies on the first to third upper storeys. Situated behind the staircase is a patio, via which a number of interior rooms are lit and ventilated (fig. 2). The exterior brickwork walls taper from the ground storey to the storeys above (56 cm in the cellar, 36 cm on the 3rd storey).
Heating was previously realised in a variety of ways, with individual stoves for wood, coal, gas, electricity, or individual gas-fired central heating systems. Water heating was also realised with various different systems. From the available accounting documents, it was possible to determine that the primary energy consumption for room heating and domestic water heating was 315 kWh/m² p.a. (fig. 4).
Since construction of the building, no energy-oriented improvement had been realised, except for the replacement of a few windows and some elements of the building services equipment. Leaks in the roof area, moisture damage on the exterior walls, damage to the wooden beam ceilings, and heavy rust in the balcony support elements meant that a comprehensive refurbishment was necessary.

Fig. 2: Upper storey floor plan after refurbishment. The light shaft was converted into an indoor bathroom.

Hamburg standard | EnSan

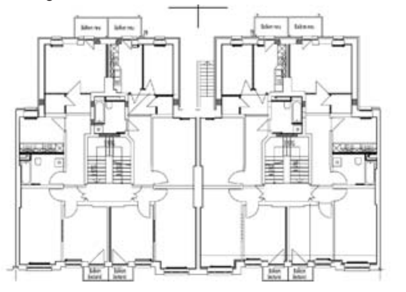

Fig. 3: Light shaft before refurbishment

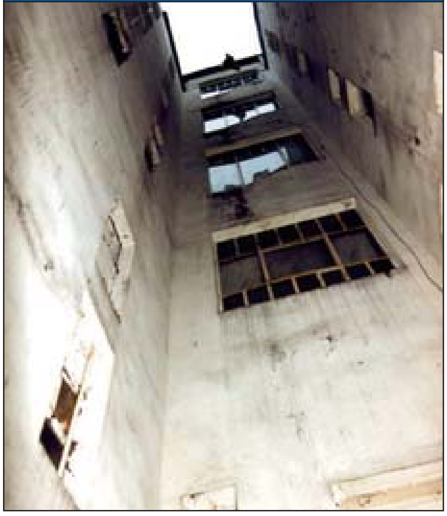

Fig. 4: Selected building data

Year of construction	1907
Location	Kleine Freiheit, Hamburg
Construction	Solid construction
Living area and usable floor area (energy reference area) Before refurbishment After refurbishment	
Area A_U before refurbishment	1,836 m²
Area A_U after refurbishment	1,936 m²
Heated building volume before refurbishment	5,739 m³
Heated building volume after refurbishment	6,049 m³
A/V ratio before refurbishment	0.40 m⁻¹
A/V ratio after refurbishment	0.35 m⁻¹
Primary energy consumption based on A_U (calculated)* before refurbishment	315 kWh/m² p.a.
Heating	247 kWh/m² p.a.
Domestic water heating	68 kWh/m² p.a.

** The electricity consumption was multiplied by 2.8 in accordance with GEMIS*

Refurbishment of Gründerzeit houses

- Focal areas of refurbishment include: renewal of the building services equipment, elimination of moisture damage in the cellar area and at the bases of walls, the facade, renewal of the roof cladding, improvement of thermal insulation and noise insulation, and redesigning the layout of the flats.
- Special attention is to be paid to the refurbishment of the ceilings and of the roof, because the wooden beam ceilings may be infested with pests; the supports of the cellar ceiling are at risk of corrosion, especially in the concealed area at wall connections.
- Due to the preservation of the facade (which is worth protecting), thermal insulation can be improved by means of interior insulation. The rear facade, the roof, and the cellar ceiling can be insulated in the standard manner.
- Elaborate décor and fittings, such as stucco or stoves, can lead to high refurbishment costs.

▶ Refurbishment concept

The concept which arose after a comprehensive appraisal, was to refurbish the mirror-image building halves with different levels of energy-optimisation, so as to enable a comparison between the energy requirement and the measured energy consumption, and also to compare the refurbishment costs.
The standard building (left building half) was refurbished according to the requirements of the Hamburg climate protection programme. This stipulates slightly stricter energy requirements than the German Energy Saving Ordinance. The EnSan building (right building half) was modernised with a higher level of energy-optimisation in accordance with the EnSan support initiative (see fig. 5).
A modulating condensing gas boiler (60 kW) with two buffer storage tanks (each 1,000 l) serves to generate heat for both building halves. A solar thermal system with a collector surface area of 30 m² supports the entire building's supply of heat (primarily water heating).

Fig. 5: U-values of the building elements before and after refurbishment

U-value of building elements in W/m²K	Before refurbishment	After refurbishment	
		Standard building	EnSan building
Windows	2.6 – 5.2	1.50	1.30
Rear facade	1.1 – 1.98	0.28 – 0.30	0.19
Front facade, ground storey	1.1 – 1.75	0.52	0.52
Front facade, 1st to 3rd upper storeys	1.1 – 1.62	1.62	0.61
Roof	0.76 – 1.52	0.15 – 0.20	0.15 – 0.19
Cellar ceiling	0.76 – 2.31	0.35 – 0.50	0.18 – 0.39

Building envelope

The historical facade was to be preserved. For this reason, the EnSan building was insulated by means of a non-vapour retardant interior insulation with 5-cm-thick calcium silicate panels which are protected on the inside by a gypsum fibre panel. Between the gypsum and silicate panels is a 2.7-cm-thick layer of air. The refurbishment of the standard building's front facade was realised without insulation measures as of the 1st upper storey (except for the window reveals). The exterior insulation applied to the rear facades was 10 cm thick for the standard building, and 16 cm thick for the EnSan building. The roof insulation, the cellar ceilings, and the floors of the rooms which have no cellar beneath, were significantly improved in comparison to the initial state.

Beam head refurbishment

One focal area in the EnSan project was the refurbishment of the wooden beam ceilings and their integration with the exterior walls. The front facade of the EnSan building was insulted on the inside with calcium silicate panels, which meant that the beam heads would form a thermal bridge. Condensation on the beam heads, combined with the prevalent temperatures in the flats, could have resulted in ideal conditions for growth of harmful fungi. The newly developed beam head structure prevents direct contact between the wood and the masonry, in that the ceiling beams are extended by an insulated flat steel bracing in the area of the wall connection. This thermal isolation solution can be implemented regardless of the thickness of the ceiling beams (fig. 7).

Fig. 6: Different refurbishment specifications for the structurally identical building halves

	Standard building	EnSan building
Refurbishment standard	Hamburg standard	EnSan standard; 50% reduction of primary energy consumption, success verified by monitoring
Historical facade	No thermal insulation	Interior thermal insulation
Beam heads of the wooden beam ceilings	No thermal isolation	Thermal isolation from the exterior wall
Ventilation	Windows, air exhaust system in bathrooms, lavatories	Decentralised ventilation system with heat recovery
Control of the heating / ventilation system by the tenant	Conventional thermostatic valves	Electronic control unit in corridor, in combination with thermostatic valves

Fig. 7: This view shows refurbished beam heads with steel bracing and the connection to the exterior wall with tension anchor..

Fig. 8: Air sealing of the ceiling and dormer wall

Interior insulation

In principle, interior insulation increases the risk of condensation behind the insulation during winter, and reduces the wall's ability to dry out. As connecting interior walls and ceilings cause increased heat losses due to thermal bridges, the use of interior insulation calls for careful planning. As an interior insulation material, calcium silicate panels are the most effective system available today. This vapour-permeable construction material has high capillary suction power. Possible condensation behind the insulation layer is distributed and temporarily stored by means of the capillary-active properties. In addition, due to its pH value, calcium silicate is resistant to mould, and has excellent fire-protection properties. If exterior insulation is impossible due to design considerations, interior insulation with calcium silicate represents a very good alternative.

▶ Results

The total energy consumption of the building is being recorded. In addition, in four selected flats (one in the standard building), a measuring system is installed which determines the consumption of heat and electricity, the circulation losses, the temperature, the indoor air humidity, and the temperature profiles in the exterior walls / beam heads.

The results from 2007 reveal that the energy-oriented refurbishment reduced the heating energy consumption by more than 70%, and even by more than 80% in the EnSan building, even though the ventilation systems were only used sporadically. This is a primary reason why the actual consumption is slightly higher than the requirements (figs. 9 and 10).

The effect of the interior insulation is evident on the inner side of the exterior walls. In the EnSan building, the surface temperature is noticeably higher than in the standard building.

Fig. 9: Energy consumption after refurbishment for the year 2007, based on 1.936 m² A_U

	Standard building		EnSan building	
kWh/m²p.a.	Final energy	Primary energy	Final energy	Primary energy
Thermal heat	39.7	71.3	32.3	64.9
Hot water	17.0		24.8	
Auxiliary energy, pumps, control, ventilation	2.1		2.3	
Solar energy system, yield	6,215.			

Fig. 10: Primary energy requirement comparison based on A_U, calculated according to the German Energy Saving Ordinance

Primary energy requirement as per German Energy Saving Ordinance (kWh/m² p.a.)	Standard building	EnSan building	Reference value for new buildings, German Energy Saving Ordinance 2007
	66	42	78

Fig. 11: Gross construction costs in cost groups 200 – 500 as calculated on the basis of the living area and usable floor area (1,391 m²), *based on A_U

Construction costs	Total	Energy-oriented refurbishment	Energy-related additional costs, EnSan building	
	1.495,- Euro/m²	704,- Euro/m²	232,- Euro/m²	167,- Euro/m²*

Quality assurance

The energy-oriented refurbishment of Gründerzeit houses places high demands on the conceptual design and construction work. In addition to a detailed appraisal, which included measurements, laboratory research, and simulations conducted by TU Hamburg Harburg, professional on-site quality assurance played an important role. This was realised by the Passive House Institute in the course of three construction site inspections. The assessment focussed on ventilation technology / air tightness (blower door test), thermal insulation, and thermal bridges. In practice, it became evident that establishing air tightness in old buildings of this type is highly laborious. Problems include leaky building connection walls, and unplastered exterior walls at the level of the wooden beam ceilings, as these are barely accessible in some instances.

Conclusion

The refurbishment of the Gründerzeit house in Hamburg was a success. The target of reducing the primary energy consumption by at least 50% was surpassed. The heating energy saved in the EnSan building is over 80% compared to the initial state, and the heating energy consumption is approximately 25% below that of the standard building, even though the installed ventilation systems with heat recovery were barely used. Here, there is further potential for savings. The occupants should not have the possibility of switching the system off completely. It would make sense to have a minimal air change ensured by the system, and to design the controller for room temperature and ventilation so as to make it self-explanatory for the users.
Particular attention was paid to the refurbishment of the beam heads in conjunction with interior insulation. The newly developed beam head structure meets the criteria, and can be implemented successfully from a thermal and hygric point of view. Thus, complete thermal insulation can also be guaranteed for facades which are worth preserving.
The implemented refurbishment solutions can be transferred to future projects with similar requirements. For instance, this applies to the refurbishment of balcony supports and beam heads, the successful implementation of interior insulation with calcium silicate panels, and the experience gathered regarding the air tightness of the building.

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ADDITIONAL INFORMATION

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- This projectinfo brochure is also available as an online document at www.bine.info

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