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Examples of high performing school renovations applying prefabricated wooden elements in Austria

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Abstract
The renovation of buildings using prefabricated wooden elements is of high interest for the European Commission. The work presented here shows examples of technical measures and solutions for the building envelope, interior, the building services and use of renewables from different nZEB school building renovations in Austria.

Keywords – school renovation; prefabricated elements; energy efficient buildings; renewables

1. Introduction

During the last 20 years increased efforts have been made not only by the national government through subsidies but also by research and development and by demonstration projects to increase the renovation rate in Austria. Since 10 years there is a strong development towards the application of prefabricated wooden elements for roof / façade constructions to support secure production processes off site as well as a quick and high on site renovation quality. Within the technology-programme “Building Of Tomorrow” of the Austrian Federal Ministry of Transport, Innovation and Technology, together with financial support of the Austrian Climate and Energy Fund, a lot of example and demonstration buildings have been carried out last years.

Lessons learned and useful experiences can be derived from measurements and studies on these buildings. And at the moment more projects on lowering the costs of the technology using prefabricated timber elements are implemented to be simple repeatable solutions for the mass of buildings. Within the European IEE-project RENEW SCHOOL frontrunner school buildings using the prefabricated wooden elements have been analyzed regarding technical solutions and cooperation models used. Some Austrian examples will be shown in this presentation, describing constructive details and solutions of the building services. The difference to previous work in this field is the comprehensive focus on the use of prefabricated wooden elements together with IEQ solutions in these example buildings.

2. Austrian example “Schwanenstadt”

The RENEW SCHOOL frontrunner school buildings have been found by setting up and assessing two main criteria: First that the buildings use some kind of prefabricated timber in parts of the construction, second that the buildings are educational buildings (e.g. kindergarten, school buildings). The following described Austrian frontrunner school is a renovated building, used prefabricated wooden façade elements and renewable energy for most of the energy consumption.

A. Renovation process and construction

The first “passive-house” school renovation in Austria is located in Upper Austria. It should have been a showcase for other municipalities. Schwanenstadt is a local administrative centre with about 4,300 inhabitants and 4 different schools.

The secondary school was built in 1972/73, renovated and extended in 2007. The main contractor was the housing association „NEUE HEIMAT Oberösterreich“, the most important person of planning and pushing the project was the architect Heinz Plöderl, from “PAUAT Architekten”, the building owner is still the municipality of Schwanenstadt. The heated gross floor area was nearly doubled and comprises 6,835 m² after renovation.

The main targets of the renovation were the attainment of the passive house standard by increase of compactness, a “holistic” approach - the use of ecological building materials (approval by LCA of components) and renewable energy sources as well as the improvement of the user comfort and the indoor air quality. The renovation work was wished to be made without disturbance of the school operation and without moving the pupils to external facilities.[1]

The situation of the existing building was very poor (see also Fig. 1).

- Precast concrete skeleton construction
- Energy use for heating and domestic hot water ~ 615.000 kWh/a
- Very bad natural and artificial lighting
- Partly structural damages of the concrete construction
- Insufficient space supply (2 dislodged classrooms)

Fig. 1 Secondary school of Schwanenstadt, entrance view before (left) and after (right picture) (Source: PAUAT Architekten, AEE INTEC)

The former position of the windows was inside the concrete pillars. The prefabricated modules were prepared to cover the pillars from the outside with 12 cm of insulation and the concrete wall with about 55 cm of cellulose insulation blown in on-site. Additionally on the interior side of the wall gypsum plaster boards were removed as well as the concrete lintel of the windows. So after the renovation, more thermal mass could be used.

A frameless window construction was simulated and tested to be used and applied in the prefabricated elements for better thermal performance of the connection outside wall and window. And a really interesting point was an on-site testing of a first developed element onto an exemplary classroom in the Southern part and first floor of the building.

Constructive measures at a glance [2]:

- Thermal insulation of the outside walls done mostly with cellulose and timber frame construction (U=0.11 W/m²K) of the prefabricated timber facade modules integrating
- Special developed frameless and thermal bridges optimized triple-glazed windows with a total U-value of 0.9 W/m²K
- Timber frame with cellulose insulation also on the old ceilings (U=0.10 W/m²K)
- Insulation beneath the ground ceiling with blown in crushed cellular glass (U=0.17 W/m²K)
- Opening of interior areas via transparent sawtooth roofs to increase the use of daylight and installation of exterior shading to prevent overheating in summer
- A radiance-controlled shading system was installed for reducing overheating hours in classrooms

Fig. 2 Prefabricated elements for the 3rd floor in the secondary school of Schwanenstadt, with bottom metal frame, deviding the 3rd from the lower floors because of fire precaution reasons (Sources: PAUAT Architekten)

An annual heating demand of 14 $kWh/m^2_{TFA}a$ after the renovation was calculated by PHPP; the pressure test showed a result of 0.6 h^{-1}. Before the refurbishment the annual heating consumption was about 122 $kWh/m^2_{TFA}a$.

B. Energy and building services, comfort

For the heating system they installed a 110 kW Pellet boiler coupled with a 1,860 liter buffer storage tank and an integrated 92 liter hot water tank supplied by the Pellets boiler and electricity outside the heating period. A solar thermal system with 15 m^2 solar collector area was planned to be installed by the pupils but not realized yet. There is a separate, outside temperature-controlled, supply and return system for the heat distribution from the buffer storage tank, accessing one radiator per classroom equipped with a thermostatic valve, and a separate time-controlled circulation system for the hot water supply.

A decentralised mechanical ventilation (for each single classroom) with 80-90% effective heat recovery was installed. The volume flow rate of the decentralized mechanical ventilation system is about 100 - 500 m^3/h per classroom. For larger rooms, bigger ventilation units with a higher flow rate were chosen. The ducts of the ventilation units had been integrated into the new facade design (ventilation grilles – see on the left picture of Fig. 2). 68 m^2 of façade PV-modules were installed with 6.7 kW_{peak} load.

Table 1. Overview of the measurement results in the renovated secondary school of Schwanenstadt – m^2 are specified as treated floor area (TFA) if not mentioned otherwise (Source: AEE INTEC [3])

Measurement period 1 (MP 1): 1 June 2007 – 31 May 2008, Measurem. p. 2 (MJ 2): 1 June 2008 – 31 May 2009				
			MP 1	MP 2
Measured heating consumption [kWh/m²a]			18.59	21.89
Measured heating consumption, weather- and temperature-corrected [kWh/m²a]			19.29	18.40
Total power consumption excluding preheating supply air [kWh/m²a]			17.57	18.23
Electricity consumption for preheating supply air [kWh/m²a]			2.45	1.35
	MP 1		MP 2	
Final energy consumption [kWh/m²a]	48.44 (TFA)	41.82 (GFA)	52.91 (TFA)	45.67 (GFA)
Primary energy consumption [kWh/m²a]	59.69 (TFA)	51.52 (GFA)	59.64 (TFA)	51.40 (GFA)

Beside measurements on the energy consumption (see Table 1. above), there had been made comfort measurements in 4 classrooms. The summary of these measurements can be found in Fig. 3. The method on how the energy consumption and the comfort parameters have been measured is detailed explained in a national report [3]. There had been set sensors for the room temperature, relative humidity and CO_2-concentration placed in four different classrooms at chest height of teachers fixed onto the wall.

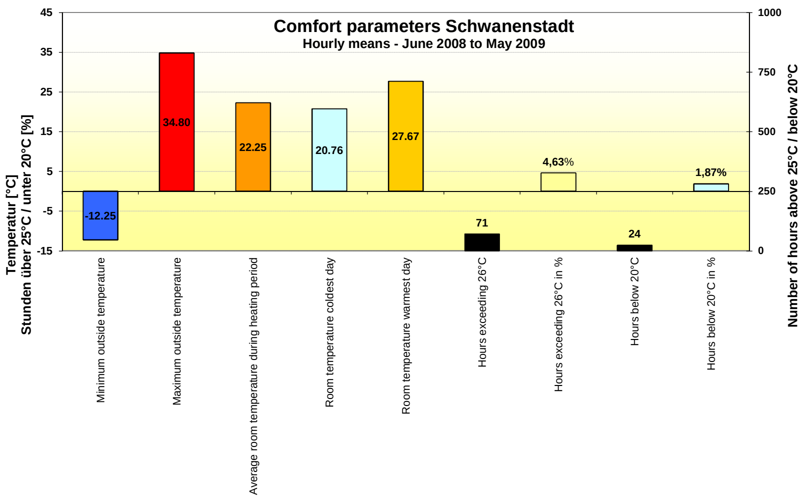

Fig. 3 Measured comfort parameters of the Secondary School Schwanenstadt during school operation from 8 a.m. to 5 p.m. (Source: AEE INTEC [3])

Compared with other recent measurements in Austrian schools the values are in a very typical range and show that the average of the school buildings is performing very well. Some of them have problems with overheating with more than 10% hours exceeding 26°C during school operation. There will be more attention on the summer comfort in future.

3. Other Austrian examples and conclusion

All of the Austrian frontrunner school renovations use very simple prefabricated wooden façade elements without integrating ventilation ducts or cable-work. They have a biomass based central heating system serving partly hot water for the gym and the cleaning facilities in decentralized hot water storage tanks. Most of them use PV-modules for power-generation on the roof, in one case also on the façade. The used technical solutions are listed in Table 2.

Table 2. Overview of applied technical solutions in the Austrian frontrunner school buildings

	Facilities included in the façade elements	Energy supply system	Ventilation system
Schwanenstadt	Cellulose insulation, windows, airtight layer, ventilation ducts	Pellet-boiler for heating and hot water, partly electricity supplied hot water tanks; PV-facade: 6.7 kW_{peak}	Decentralized balanced ventilation (500 m^3/h per unit in one classroom); natural night ventilation
Neumarkt [4]	Mineral wool / cellulose insulation	Fed by near biomass district heating,	Centralized balanced ventilation (14.000 m^3/h), heat and humidity recovery; partly natural night ventilation
St.Leonhard/ Arnoldstein [5]	Windows, bore holes for on-site cellulose insulation, cables	Pellet boiler, PV 5 kW_{peak} on the roof	Centralized balanced ventilation (2.000 m^3/h), heat and humidity recovery
Rainbach [6]	Mineral wool / cellulose insulation	Biomass-chips boiler 150 kW, 20 m^2 solar thermal system, buffer storage tank 2,300 liter; PV 50 kW_{peak}	Centralized balanced ventilation (10.000 m^3/h), heat and humidity recovery

The measurement results show that these school renovations made in the "RENEW SCHOOL way" are performing well both in energy and comfort related requirements.

Acknowledgment

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