Ansitz Kofler in Bolzano/Italy: Energy retrofit to near passive house standard and towards zero emission for heating and cooling.

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ABSTRACT

In 2007 the orangery of “Ansitz Kofler” (listed building dating 1749), was refurbished – both aesthetically towards historic roots and energetically to low energy building. Applying efficient insulation (internal and external – meeting preservation of monuments’ demands), windows with passive-house-standard, ventilation with heat-recovery and geothermal heat-exchanger, and avoiding thermal bridges, the design heating-demand was lowered from 450 to 30 kWh/m²a (CasaClima-Certfication A+). A pellets-boiler satisfies the remaining demand without CO_2. EURAC monitors the building’s energy-consumption, indoor-comfort and hygrothermal-wall-behaviour since October 2008 with 70 sensors. The measured heating-demand is slightly higher than calculated (also due to user influence), but still at absolute low values. Indoor climate has proven comfortable with warm surfaces and without need for active summer-cooling. Finally, the monitored wall profiles confirm good hygrothermal performance.

KEYWORDS

6-8 keywords

INTRODUCTION

Ansitz Kofler in Bozen (Italy) was built in 1749 – and had Wolfgang Amadeus Mozart as guest in 1969. The Orangery (see Figure 1.a), which was erected a little after the main building, was transformed into a housing unit in 1925. Before the energetic refurbishment the energy demand for heating was about 450 kWh/m²a. The reason for the high energy demand was on one hand the low thermal performance of the massive stone walls with an U-value of 2.1 up to 2.6 W/(m²K) and the with large windows on the East and Westside with an U-value of 3.0 W/(m²K) and on the other hand the unfavourable form of the building with its A/V-ratio of 0,8 1/m.

First objective of the refurbishment was to get back the historical architectural appearance of the listed building and to adapt space for residential purposes in consultation with the provincial office of historical monuments. Equally important objective was to abate the high energy consumption of the building and to create a high living comfort. In reaching this aims only ecological and healthy materials should be used. The intended energy performance was a ClimaHouse A+, which means a heat consumption under 30 kWh/(m²a).

Figure 1. The Orangery of Ansitz Kofler, (a) status from an old photography before the transformation into housing unit in 1925 (b) before and (c) after the refurbishment in 2007/2008. It was explicit whish of the owner to preserve also the ancient Jasmin.

Both the active energy system of the refurbished building and the hygrothermal behaviour of the different solution for wall insulation as well as potentially critical points and indoor comfort have been monitored with more than 70 sensors (records every 5-10 minutes) and scientifically evaluated since 2008 [1].

Within this presentation apart from describing in brief the refurbishment (which has been described in detail in [2]) and reporting monitoring result, the focus is given to aspects which are specific for the refurbishment of historic buildings and conservation issues.

RETROFIT OF THE BUILDING

Intervention on the building envelope

Being the building listed, the appearance of the façades had to be conserved. Therefore on this eastern façade, where there is a direct transition from the Orangery to the main building, application of insulation was only possible on the inner side. Thanks to the access balcony on the first floor of the western facade, an aesthetically

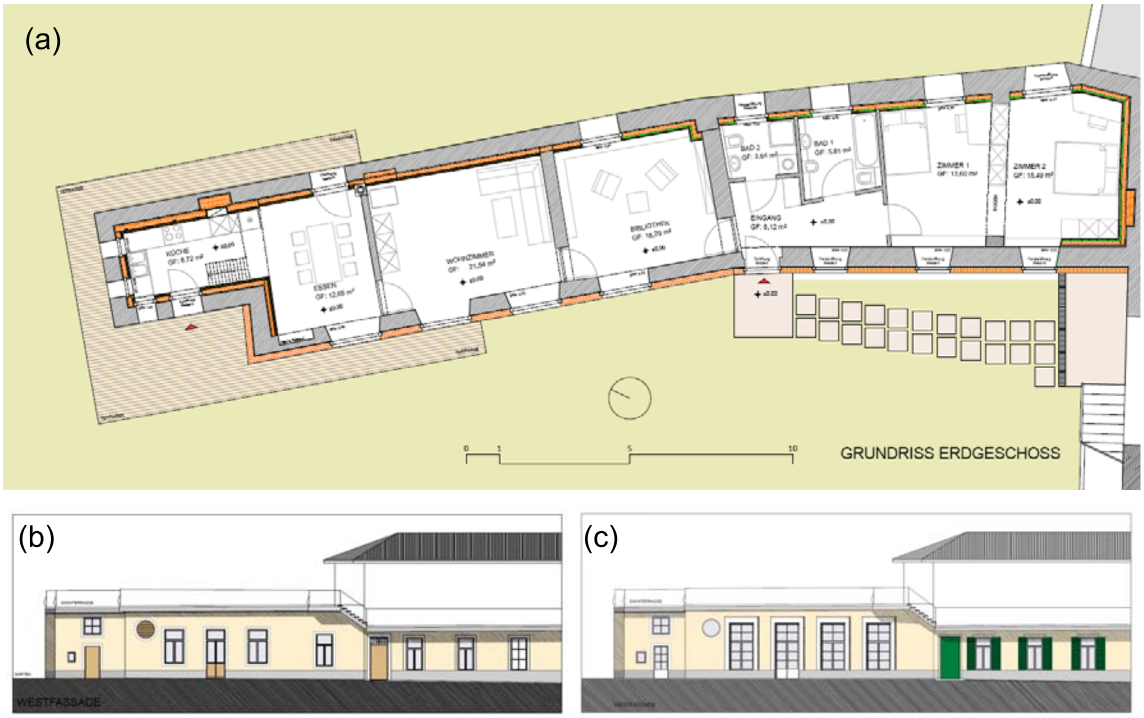


Figure 2. Plan view (a) and western facade (b) before & (c) after refurbishment.

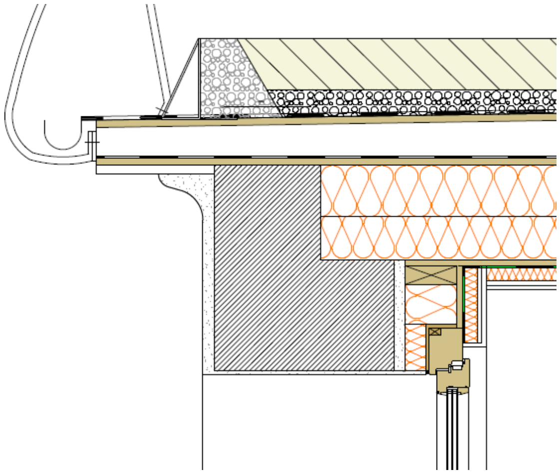
proper transition to the existing facade of the not yet refurbished upper floors was possible also with exterior insulation. Amply overlapping areas with both interior and exterior insulation avoid thermal bridges. Both in the case of the exterior and interior insulation the triple glazed windows were placed in the insulation line. Despite the lower g-value of the new windows, the total solar gains increase a little, due to the influence of larger of windows for ancient orangery resemblance (see Figure 6).

The roof was refurbished from outside in order to preserve the existing roof beam structure, inner wood boarding layer and interior plaster. The floor was removed until the foundation and rebuild with 20 cm thick insulation boards XPS avoiding ascending moisture infiltration from the ground and from the walls.

To exclude damage of the internal insulation and to guarantee the highest efficiency of the ventilation system, all connection details were developed and conducted in the sense of optimal air tightness. The blower door test (DIN 13829, procedure B) after

Table 1. Constructive elements and reached U-values

Element	Old U-Value	Solution	Material	Thickness	New U-Value
Wall	~2.6 W/m²K	Ext. insulation	mineral wool (Flumroc)	20 cm	0.16 W/m²K
		Int. insulation	mineral wool (Flumroc)	14 cm + 4 cm	0.17 W/m²K
			wood fibre	14 cm + 4 cm	0.19 W/m²K
Roof		Ventilated green roof	mineral wool (Flumroc)	14 cm + 12 cm (between beams) + 4 cm	0.17 W/m²K
Floor			XPS	20 cm	0.17 W/m²K
Window			triple glasing		Ug: 0.6 W/m²K Uf: 1.45 W/m²K



Roof

- Clay board, 25 mm
- Insulation panel FLUMROC, 40 mm, installation layer
- Vapour retarder (s_d=2)
- OSB-panel 15 mm
- Insulation panel FLUMROC, glued holohedral, 120 mm + 140 mm between beams
- Roof boarding, 15 mm
- Sealing sheeting, diffusion-open
- Ventilation level, 80-125 mm

… green roof

Exterior wall (east)

- Clay board, 25 mm
- Insulation panel FLUMROC, 40 mm, installation layer
- Vapour barrier (s_d>100)
- OSB-panel
- Insulation panel FLUMROC, 140 mm, glued holohedral,
- Interior plaster, 30 mm, leveling layer
- Natural stone masonry
- Exterior plaster ca. 20 mm

Figure 3. Green roof and eastern façade section view with window integration detail. Description of layers from inside to outside.

termination of the construction works the blower door test attested n_{50}=0,66 1/h. Special conservation related aspect here: Since the existing tiled stove was stated as listed object, a new insulated chimney pipe had be foreseen, which provides fresh air supply independently from the ambient air.

Areas with internal insulation do have an aluminium vapour-barrier (s_d>100) which overlaps and is glued with the vapour retarder (s_d=2) of the ceiling construction. The complete electric and hydraulic installation was realised in a separate installation layer between vapour barrier and ambient. Any penetrations and lesions of the vapour barrier were avoided. To check this a first blower door test was performed after the preliminary installation and before the application of the inner covering.

Elimination of thermal bridges

To prevent thermal bridges where partition walls abut outside walls, the internal wall was cut and insulation placed vertically against the wall. Where new partition walls were built up, interspaces to the external wall were left in order to place insulation, OSB-boarding and vapour barrier behind.

In other situations the wall was a bearing one and thus could not be cut. Therefore insulation on the border had to be applied. In one case in the corner an old chimney

Figure 4. The ancient tiled stove was preserved and got a separate air supply. Also preserved should be the ancient vine at the eastern facade

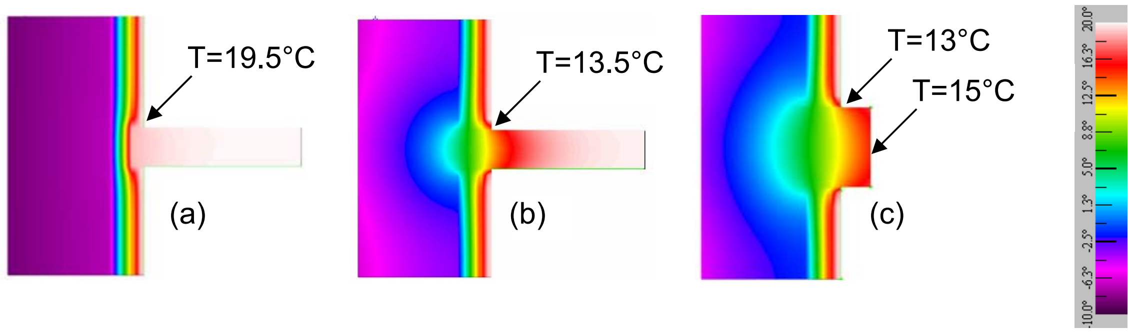


Figure 5. 2-dimensional simulation of partition wall abuting outside wall with Therm 5.2 for (a) thermal division (b) no thermal division and (c) special situation at the arch.

was found – and by insulating that internally the supplementary insulation along the partition wall could be avoided.

Not in all points the elimination of thermal bridges was possible: In the bedroom an arch as separating and supporting element could neither be cut nor insulated alongside. Internal insulation and vapour barrier were brought there until the borders of the arch and finished with plaster. A sensor for temperature and humidity is monitoring this potentially critical point.

Intervention on the building services

The ventilation system is equipped with a central air to air heat recovery resulting in 4'300 kWh/a saved – corresponding to 27 kWh/m²a. Furthermore a ground-air heat exchanger system for the preheating of the external air in winter and the cooling of the external air in summer has been realised.

The refurbished building is heated with low-temperature floor heating systems, controlled in eight circuits. Replacing ancient gas boiler with a pellet boiler, which supplies the whole building complex with warm water for heating and domestic hot water, makes the whole system climate neutral.

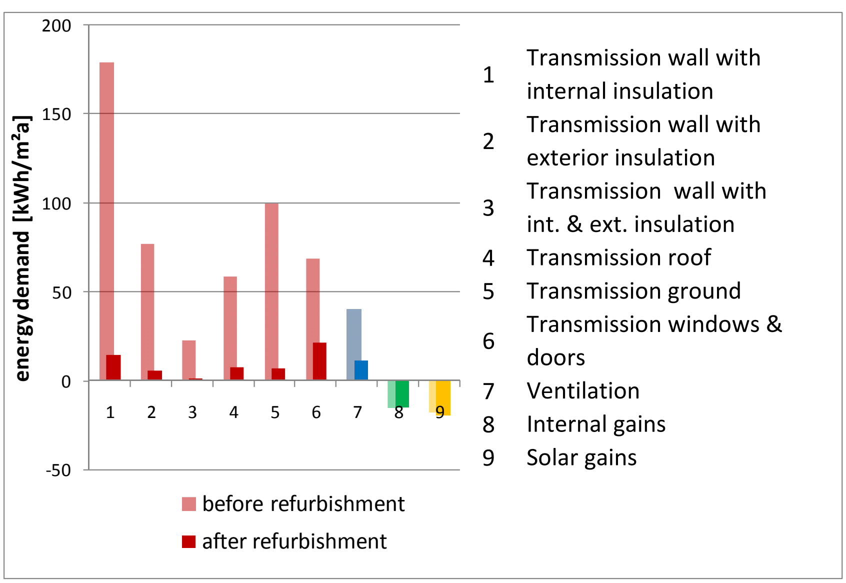


Figure 6. Energy demand of the building before and after the refurbishment.

Figure 7. Technical installation (e.g. the ventilation system) were positioned in a new "plant room" above the kitchen, taking advantage of the amply height of the rooms

MONITORING

Energy consumption for heating

The energy consumption for heating was in both the monitored years higher than the value calculated (<30 kWh/m²a for 2763 Kd): 54.2 kWh/m²a in 2008/2009 (with 2278 Kd) and 56.3 kWh/m²a in 2009/2010 (2409 Kd). This deviation is still under evaluation, but preliminary results indicate various reasons for it – which are all not specifically linked to the fact that it was a historic building to be refurbished: (i) reduced internal loads due to frequent absence of the tenants, (ii) reduced solar contributions due to extensive use of shading for privacy reasons, (iii) measured efficiency of the heat recovery of 0.75 instead of 0.9 as well as (iv) repeated switch off of the ventilation system – both due to congested filters and thermal discomfort in intermediate season (too low temperatures due to soil heat exchanger [3]).

Although being the consumption nearly twice as high as the calculated demand, the absolute values are still very low compared to the consumption of the not refurbished building.

Comfort

Monitoring indoor temperature and humidity confirmed the success of the intervention. Both in winter and summer comfort conditions are respected, as can be seen in Figure 8: Especially when considering the adaptive comfort model (EN 15251, for not climatised environment) the values lay well within the range of comfort, but also applying the more rigid ASHRAE comfort model (developed mainly for climatised environment) comfort conditions are nearly always met – the sometimes lower values in winter are due to the choice of the tenant to have lower air temperature in the bedroom.

Behaviour of thermal mass

In Figure 9 three examples of the monitored behaviour of the thermal mass are presented: (a) shows the attenuation of diurnal temperature cycles – red being the indoor air, purple the surface temperature of the wall with interior isolation and thus less thermal inertia and green the surface temperature of the wall with exterior insulation, where the thermal mass of the ancient stone further decreases the cycles.
In (b) the development of temperatures over a three weeks period can be observed: The thermal mass of the exteriorly insulated wall is first heated up (light green following dark green with some delay), while a quite sudden drop of the outside

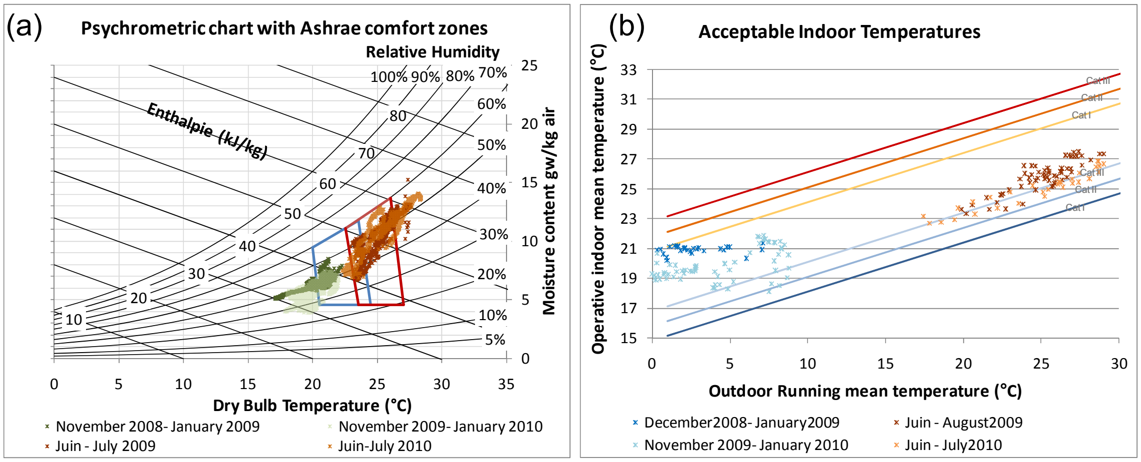


Figure 8. Temperature and humidity during winters 2008-2009 and 2009-2010 as well as summers 2009 and 2010 (a) in the psychometric chart with indication of comfort zones (ASHRAE 1993) and (b) in the adaptive comfort model according UNI EN 15251.

temperature by more than 5 K caused the wall to cool again after Christmas. The same delay in can be observed in summer (see Figure 9.c), both of the inner surface of the wall with exterior insulation versus its surface temperature and of the surface temperature of the interiorly insulted wall versus the surface temperature of the exteriorly insulated one.

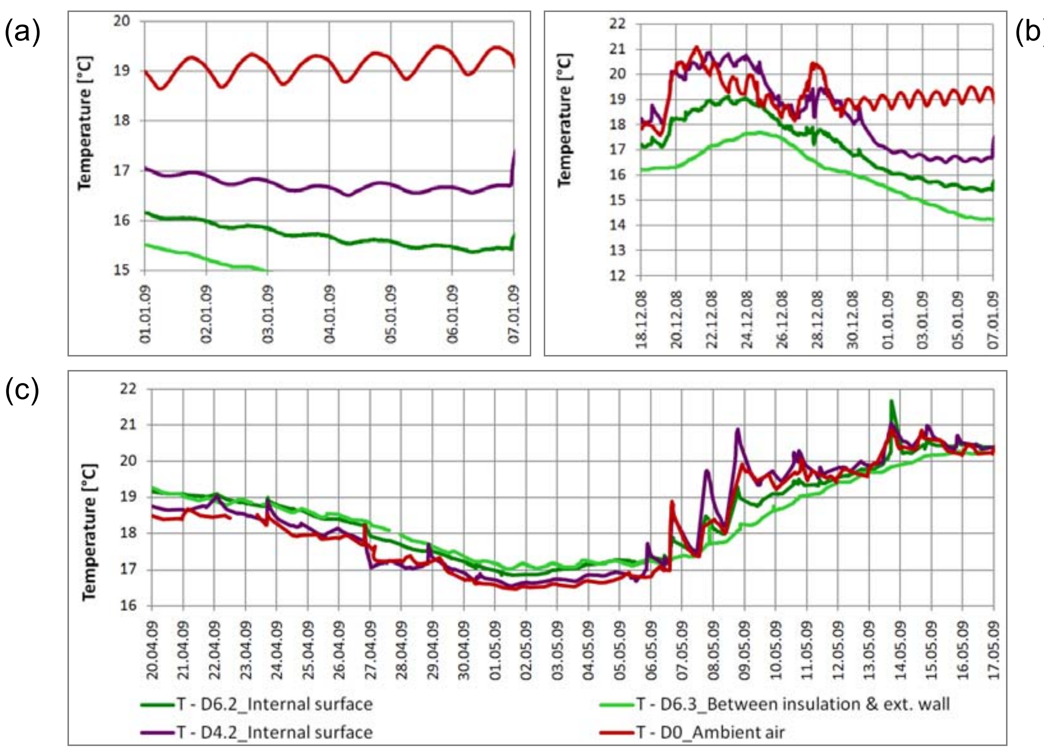


Figure 9. Three examples for the behaviour of the thermal mass, showing the higher inertia versus indoor climate of the wall with exterior insulation.

Hygrothermal behaviour of wall

Different ambient conditions inside and outside a construction cause vapour to pass through a wall – in winter conditions usually from inside to outside. With internal insulation putting the whole ancient construction in "cold" conditions, this might lead to the condensation and accumulation of humidity within the construction. Two approaches can prevent problems: (a) a vapour tight solutions prevent humidity to pass from inside to the cold parts of the construction, (b) capillary active insulation materials support the transport of humidity "back" to the ambient under favourable conditions.

The second option, being more "failure safe", is today usually favoured. However, extended practical experience is available for insulation thickness up to 8 cm. Since for Ansitz Kofler the planners aimed at considerably higher insulation values, they opted for the solution with vapour barrier (s_d>100) – putting high effort in the avoidance of any potential failure: penetration of the vapour tight layer were avoided, electric and a hydraulic installations were realised in a 4cm thick installation layer which was again covered by 2.5 cm of plaster board, a blower door test after the preliminary installation and before the application of the inner covering attested the tightness. Finally the hygrothermal behaviour should also be monitored in order to get feedback on the success (localisation of sensors reported in Figure 10).

The monitored data indicate safe conditions both for winter and spring conditions. Figure 11.a illustrates clearly the temperature profile in the wall under winter conditions: indoor surface slightly colder than indoor air, temperature before and after vapour barrier practically identical, major temperature difference along main insulation (∆ A1.4-A1.5), and nearly no temperature difference along the ancient stone wall (∆ A1.5-A1.6) – interesting to see that main effect of the stone wall is to level out daily variations.

A look at the absolute humidity (g/m³, see Figure 11.c) demonstrates the effective operation of the vapour barrier: while indoors it varies between 7-8 g/m³ – measured values of the air and inside the construction before the barrier being very similar – outdoors it is generally about 2 g/m³ lower – also values in the construction, be it

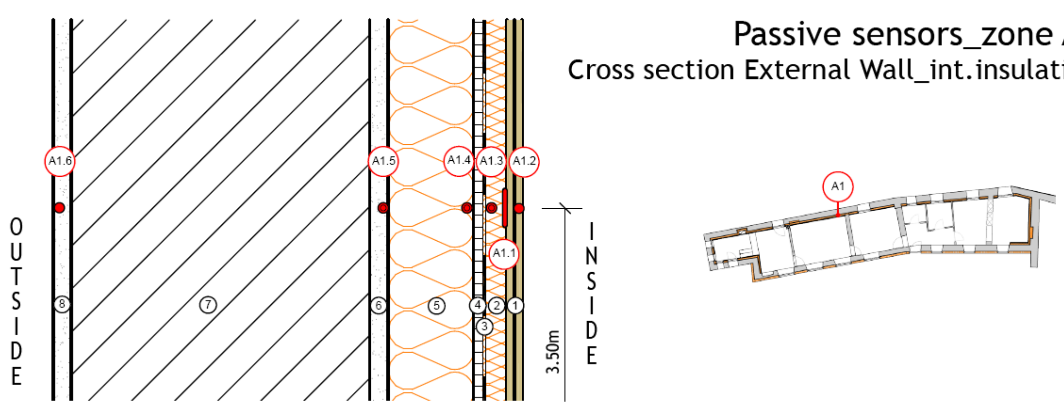


Figure 10. Localisation of sensors for monitoring the hygrothermal behaviour: A1.2 Internal surface temperature, A1.1 heatflux meter plate, A1.3 temperature and rel. humidity before vapour barrier, A1.4 temperature and rel. humidity after vapour barrier, A1.5 temperature and rel. humidity between insulation and external stonewall, A1.6 external surface temperature.

immediately after the barrier or at the interface to the ancient wall, very similar. At thelower temperature at the interface between wall and insulation, air could however only take up a limited amount of water vapour – the dotted line in Figure 11.c shows the maximum value for saturation, and the fact that it lies continuously under the absolute humidity on the interior side of the vapour barrier means, that vapour passing through a lesion of the latter, would condensate in this area. Whether this is harmful to the construction depends on whether the moisture accumulates over time or whether it is be removed under favourable conditions. Simulations to ascertain this are planned to be carried out.

The above considerations on absolute humidity level are also reflected by the relative humidity (Figure 11.b): indoors it is about 40%, before the vapour barrier due to the lower temperature 50-60% are measured, which is however a value far from any damage risk. The vapour content after the barrier results in about 35% immediately there and 80% at the interface between insulation and wall.

Under spring conditions (end of April, tenants most probably not present, Figure 11.d), the temperature indoors is lower than in the envelope construction. Also here the independent behaviour of absolute humidity before and after the vapour barrier can be observed. The monitored values of RH are for the whole construction at safe values varying between 40% and slightly above 60%.

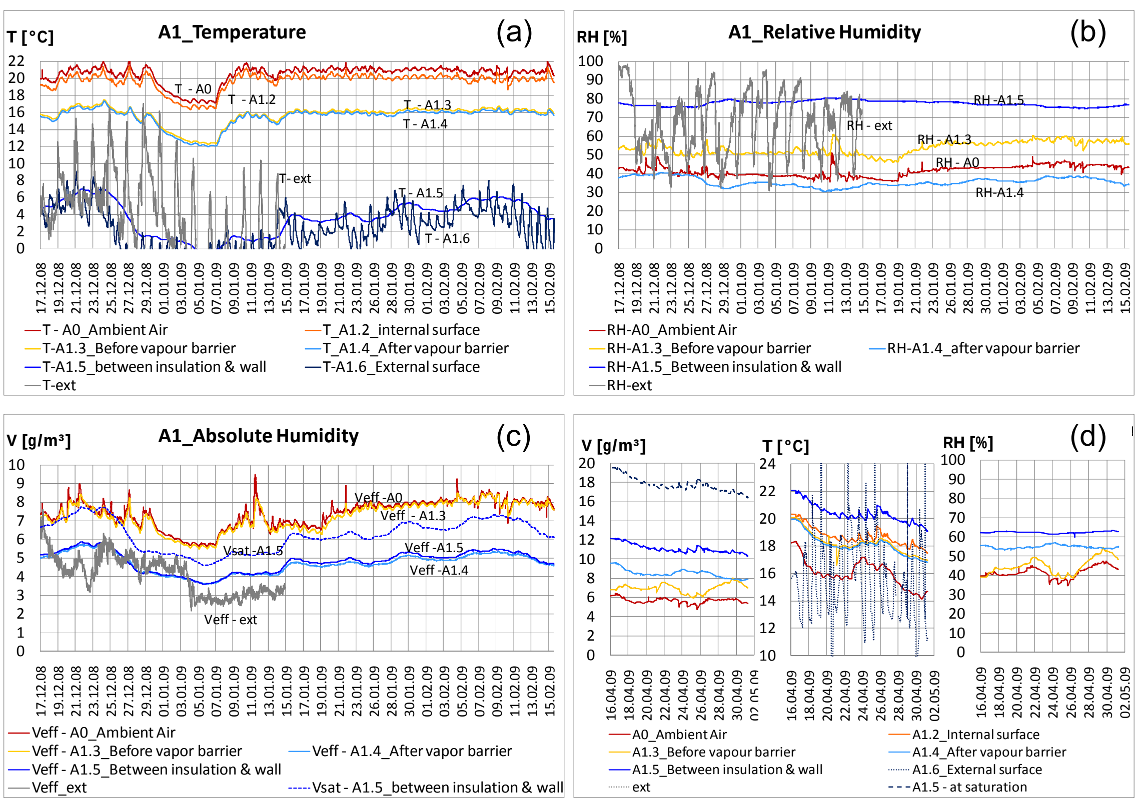


Figure 11. Temperature (a), relative humidity (b) and absolute humidity (c) during two winter-month at the monitoring profile shown in Figure 10. (d) reports the same variables for a period of two weeks at the end of April.

CONCLUSION

Even with very challenging circumstances – as in the here presented case being conservation restrictions as well as very unfavourable orientation and building shape (area/volume ratio!) – an energetic refurbishment in compliance with, yet even with recovery of cultural-aesthetic value is possible.

The monitored data indicate a higher consumption than calculated – which is with about 55 kWh/m²a however still at a very low value. The reasons for this deviation are not specific for a refurbishment of historic buildings, but are rather connected (i) to general construction and refurbishment issues as e.g. the assumption of a typical user behaviour and (ii) to some optimisation potential in the ventilation system inserting a bypass of the geothermal exchanger.

Indoor comfort has been ascertained to have been well reached with the intervention. Typical issues for historic buildings' refurbishments as e.g. the question to which extent thermal mass remains available and whether hygrothermal problems are avoided or solved, have been studied by targeted scientific monitoring. It shows the success of the specific interventions at Ansitz Kofler – and beyond that it will, complemented by dynamic simulations, help to generalise the experiences for other cases.

Finally the description of some specific solutions developed as e.g. the space for technical equipment and the air supply for the listed tiled stove complete this presentation of a successful energy refurbishment of a historic building.

Figure 12. Entrance to Ansitz Kofler.

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