Public Weigh House

Alexandra Troi, EURAC research

The research leading to these results has received funding from the European Community’s Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 260162

This document reflects only the author’s views. The European Union is not liable for any use that may be made of the information contained therein.
Location

- Bolzano, Italy
- Altitude: 269 m
- Heating days: 183
- Heating Degree Days: 2791 HDD
- Surrounded area: mountainous

Urban context

- Historic city center of Bolzano
- Building is part of the “portici” of Bolzano
- East and south façade look toward a little square, while the north façade is directed to the tight historic shopping street (“portici”) of Bolzano
History use

- **Original objective**
  - Seat of the public weigh-house (Waaghaus) up until 1780

- **Current use**
  - Ground floor: shops
  - 1st and 2nd floor: apartments
  - 1st and 2nd basement: storage

- **Expected use in future**
  - Ground floor remains shop
  - Upper floors for cultural purpose ideas:
    - museum of photography
    - regional cultural associations
    - “Künstlerbund”
    - Apartments for artists
Planning progress – use of building:

To define the use and the refurbishment project for the building, a two-stage competition will be carried out:

- Ideas competition for the **future use** of the Weighhouse
- Architecture competition for the **refurbishment project**
Planning progress – use of building:

- Ideas competition to define the future utilization concept of the Weighhouse as a “House of Photography” -> published in May 2012, selection of 10 planners and start of competition phase: beginning of July, delivery of projects: yesterday, publication of decision: 22nd November
- -> besides utilization concept it was asked explicitly to exploit the energetic potential of the building

- The winner will project and realize the refurbishment
State of progress

Planning progress – use of building:

- Ideas competition to define the future utilization concept of the Weighhouse as a “House of Photography” -> selection of winner project 22nd November 2012:
- **Ground floor**: Reception, shop, café; **Basement**: digital gallery for citizens, old photographic studio
- **First floor**: temporary exhibition; **Second floor**: atelier of city photographer, apartment caretaker, permanent exhibition “Tyrol yesterday and today”; **Top floor**: Auditorium, bibliotheca, administration
- Next steps still not clear: if the winner will project and realize the refurbishment project
Diagnosis and pre-intervention status

Dagmar Exner
Architecture/Construction

- Massive construction in natural stone (vaults)
- Wooden roof construction
- Characteristics "Portici" of Bolzano:
  - Ground floor: Walkway for the mercantile life, behind it vaults for the storage of goods, often several floors below ground level
  - On the upper floors: apartments often placed around an atrium
History construction

- Original building 13th century
- Intervention 15th and 16th century
- Extension (2nd floor) beginning 17th century
- After extension 17th century, during public ownership
- Inner walls from the last century
State of diagnosis preintervention

- **Calculations:**
  - PHPP As-is-state
  - EnergyPlus as-is-state

- **Measurements:**
  - Thermography
  - Blower Door Test

- **Documents:**
  - Report on stratigraphic analysis, diachronic analysis
    (Conservator: Adriano Salvoni 2006)
  - Project plans as-is-state
    (Architect: Dalla Bona 2006)
State of diagnosis preintervention

- **Calculations/Simulations**
  - PHPP: As-is-state

- **Measurements:**
  - Thermography (unheated building) by Christoph Franzen 02/11

- **Monitoring system:**
  - Installation 04/11 by TUDA – Update/extension 10/2011
State of diagnosis preintervention

- **Results specific space heat demand** – As-is-state – for different pressurization test results (n50)
  (VERSION I: Balance boundary excluding top floor, first and second basement floor)

<table>
<thead>
<tr>
<th>Specific space heat demand</th>
<th>Pressurization test result*</th>
</tr>
</thead>
<tbody>
<tr>
<td>390 kWh/m²a</td>
<td>3,0 h⁻¹</td>
</tr>
<tr>
<td>417 kWh/m²a</td>
<td>11,5 h⁻¹</td>
</tr>
<tr>
<td>441 kWh/m²a</td>
<td></td>
</tr>
<tr>
<td>472 kWh/m²a</td>
<td></td>
</tr>
</tbody>
</table>

* "Eine Schweizer Untersuchung benennt für "Altbauten vom 17. Jh. bis 1870" einen Wertebereich der Messungen bei 50 Pa Prüfdruck von n50 = 11,5-29 je Stunde (Mittelwert 19 h⁻¹)."

http://www.baufachinformation.de/denkmalpflege.jsp?md=2004077108843
Outdoor climate

Solar radiation, outdoor temperature, outdoor relative humidity

Air streams

Historical surfaces

Near field climate, surface temperatures

Changing of form in laboratory and on-site

Air streams

Indoor climate

Surface temperatures on constructional critical points of the thermal envelope. As: external corner, window, window reveal

Air streams
Monitoring system

**Monitoring As-is-state:**
Selected rooms will be temperate and dependent on the results on historical surfaces (indoors) they will be also conditioned regarding the relative humidity.

* Acquisition of energy consumption *

**Interventions:**
Selected rooms/surfaces: Interventions like:
- Installation of windows prototype
- Installation of interior insulation

**Monitoring after interventions**

Monitoring of window situation (as-is-state)
Before intervention
Monitoring system

- Monitoring energy consumption
- Heating up with electrical heating
- Mobile humidifier/dehumidifier
- Comfort
- Acquisition of energy demand
Monitoring layout: Second basement

Indoor climate
Monitoring layout: First basement

Indoor climate
Monitoring Layout: Ground Floor
Monitoring layout: First floor

- Electrical heating
- Indoor climate
- Historical surfaces
- Indoor surface before/after intervention
- Climate envelope-insulation and in insulation (if feasible)
Monitoring layout: Second floor

- Historical surfaces
- Indoor climate
- Electrical heating
- Indoor surface before/after intervention
- Climate envelope-insulation and in insulation (if feasible)
Monitoring layout: Top floor

Indoor climate
Surface temperatures in roof construction
Monitoring System

- Installation of electric heaters in 8 rooms of the building
- Extension monitoring system: mobile sensors
- Opening of window shutters

Aims:

- Acquisition of energy demand
- Realistic situation for measurements like: thermography, monitoring after interventions
Example of environmental monitoring results

Inner surface temperature (10.03.2011 - 15.12.2011) north wall heating with IQ-Therm interior insulation system,
Example of monitoring results

Inner surface temperature (10.03.2011- 15.12.2011) north wall heating with IQ-Therm interior insulation system,
Diagnosis pre-intervention

Evaluation of Blower Door Test:

Measurement without top floor ($V_{Netto} = 1.780 \text{ m}^3$)

Overpressure: $n_{50} = 9.98 \pm 0.04 \% \text{ [h}^{-1}\text{]}$
Underpressure: $n_{50} = 9.08 \pm 0.02 \% \text{ [h}^{-1}\text{]}$
Diagnosis pre-intervention

Evaluation of Blower Door Test:

Measurement with top floor \( V_{\text{Netto}} = 2.042.5 \text{ m}^3 \)

Overpressure: \( n_{50} = 10.05 \pm 0.13 \text{ % [h}^{-1}\text{]} \)
Underpressure: \( n_{50} = 9.1 \pm 0.02 \text{ % [h}^{-1}\text{]} \)
Further diagnosis

- **Analysis of material sample** (02/12) -> core drill hole (diameter 5 cm – length 30 cm) from exterior wall of “test room”, first floor: water absorption coefficient, porosity and density
- **Heat flux measurements** (02/12)
- **Second thermography** (02/12) with in parts heated building, combined with Blower Door

- **Opening of 2 wooden ceiling beam ends** in “test room”, first floor. 2 in the pavement – opening from above (ceiling ground floor/first floor) and 2 in the ceiling – opening from below and from above (ceiling first floor/second floor): visual diagnosis on position and state of beam ends
Diagnosis pre-intervention

Calculated annual specific heat demand of as-is-state (version I) with PHPP: 343 kWh/(m²a)

Transmission heat losses over external surfaces:

<table>
<thead>
<tr>
<th>Building Element</th>
<th>m²</th>
<th>kWh/(m²a)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exterior Wall - Ambient</td>
<td>968,41</td>
<td>157,45</td>
<td>52,53</td>
</tr>
<tr>
<td>Roof/Ceiling - Ambient</td>
<td>99,09</td>
<td>12,52</td>
<td>4,18</td>
</tr>
<tr>
<td>Floor slab/ basement ceiling</td>
<td>127,51</td>
<td>39,51</td>
<td>13,18</td>
</tr>
<tr>
<td>Ceiling 2nd floor to cold roof and ceiling basement</td>
<td>512,48</td>
<td>55,73</td>
<td>18,59</td>
</tr>
<tr>
<td>Windows</td>
<td>116,10</td>
<td>32,53</td>
<td>10,85</td>
</tr>
<tr>
<td>Exterior Door</td>
<td>9,89</td>
<td>1,98</td>
<td>0,66</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>299,72</td>
<td></td>
<td>100</td>
</tr>
</tbody>
</table>
Analysis of architectural elements

- Precise **measurement of stratigraphy** of construction elements -> drawing of detail sections with correct dimensions
- **Analysis of material parameters** (from material samples) through TUD for the Delphin database
- Documentation of the building in the DIS database
Eplus model of the whole building
- Model with Energy plus for the calculations of energy consumptions and comfort conditions
- Comparison between the models with Eplus and the PHPP results

Test room model in Energy plus:
- **Validation of the model** through the comparison between the monitored and simulated surface temperatures of one test room in the as is state
- Simulation in a 3D space of the behaviour of the wall with the interior insulation to understand the influences on the thermal mass
Analysis of architectural elements

- Calibration of model: **measurement of heat transmission** of construction elements of the thermal envelope
- **Specialists for buildings history** are analysing the whole building structure -> more knowledge on heritage value of single construction elements
- Documentation of the building in the DIS database
Diagnosis pre-intervention

New window situation:

- **Outer window frame**: from baroque period 1750/1800, originally with impost
- **Outer window sashes**: around 1900
- **Inner window sashes** + box-type window frame: 1950\(^{th}\)

- Need of a consistent window/façade concept
- Development of a 2\(^{nd}\) window prototype -> energy efficient box-type window
- Bring existing window prototype (coupled window) forward to a applicable state
Diagnosis pre-intervention
Diagnosis pre-intervention
Prototypes and support in design phase
Planning Solutions/Interventions

- Development of Window prototype (developed by Franz Freundorfer and André)

Aims:
- Based on the individual demands of the case study: adaption of the “passive house” window to the special conditions of the historic building
- Window solution should be applicable for similar historic buildings
Installation of Window prototype

Aims:
- Installation of a coupled window prototype in a “test room” with internal insulation. The room will be temporary heated up during the heating period.
- Visualize the developed prototype in the building context
- On-site testing of the prototype: conservator evaluation
- Monitoring of before and after situation in terms of surface temperatures and relative humidity
Installation of internal insulation in one test room

Installation of IQ-Therm in a north-east oriented room on the first floor. The room will be temporary heated up during the heating period. Use of clay glue for fixing the insulation panels in a removable way.

Aims:
- **Summer case/winter case:** Weighting of the influence of internal insulation on the “efficiency” of the thermal mass/energy consumption
- Observing and analysing **risk of condensation** in the layers under the internal insulation, the corners and beam ends
Planned Solutions/Interventions

- Installation of internal insulation in one test room – actual state
- Simulations of three points in Delphin by TUD:
  - Window prototype/window reveal
  - Floor (beam ends)
  - Ceiling (beam ends)

Comparison of 2 thicknesses: 5 and 8 cm
State of diagnosis pre intervention

Installation of internal insulation in one test room – actual state

Simulations in DELPHIN of **two significant points:**
- Floor (beam ends)
- Ceiling (beam ends)
- Comparison of 2 thicknesses: 5 and 8 cm with as-is-state
Simulation of beam ends floor (ceiling “portici”)
Comparison: relative humidity and temperature within the structure on a cold winter day
(Winter 2\textsuperscript{nd}/3\textsuperscript{rd} year: 12\textsuperscript{th} January)
State of diagnosis pre intervention

Simulation of beam ends ceiling -> with air flux and without
Comparison: relative humidity and temperature within the structure on a cold winter day (Winter 2\textsuperscript{nd}/3\textsuperscript{rd} year: 12\textsuperscript{th} January)
Planned Solutions/Interventions

Proposal of passive solutions
- Insulation of roof
- Insulation of baseplate
- Insulation of ceiling portici
- Higher airtightness (10.05 -> 1.5 h⁻¹)
- Substitution of windows (2.5-2.9 -> 1.2-1.4 double glazing)
- Controlled ventilation with heat recovery (85%)
- Solar collector under roof tiles (in comb. with heat pump)
Planned Solutions/Interventions

Annual heating demand 259 kWh/m²a -> 136 kWh/m²a

- Insulation of roof -> 244 kWh/m²a
- Insulation of baseplate/insulation of ceiling portici -> 188 kWh/m²a
- Higher airtightness/substitution of windows -> 150 kWh/m²a
- Controlled ventilation with heat recovery (85%) -> 136 kWh/m²a
Retrofit design
Planned solutions

Installation of iQTherm 8 cm in test room (1st floor)

- **Wooden beams in ceiling:** implementation of two different connections
- **Monitoring and comparison of both solutions:** wood moisture content, temperature and rel. humidity

**Version I: „interrupted” insulation**

**Version II: „continued” insulation**
Retrofit design
Planned solutions

Detail: endpoint internal insulation at parapet height (room 2nd floor)

Without metal sheet

With metal sheet
Retrofit design
Planned solutions

Energy efficiency solutions for the whole building:

Optimization strategy
- Building envelope and night summer ventilation optimization
- Minimizing energy consumption and discomfort
- Solution sets for building envelope and ventilation system

Detail planning and technical feasibility of passive solutions
Planned Solutions/Interventions

- Semester project on Weigh House of students of LAB (Lighting Academy Bartenbach)
- Development of concepts for daylighting of the Waaghaus
Planned Solutions/Interventions

- Semester project on Weigh House of students of LAB (Lighting Academy Bartenbach)
- Development of concepts for daylighting and artificial lighting of the Waaghaus
- Development of an energy efficient artificial lighting system responding to the demands of a protected building
Semester project on Weigh House of students of TUD “Masterstudiengang Denkmalpflege und Stadtentwicklung”

Documentation of **as-is-state of most of the “portici” – buildings**, regarding the following issues:
- Are there basement floors? How many basement floors?
- Roof areas
- Last refurbishment
- As-is state windows
- As-is state facades (historic plaster)
- Atriums
- Comfort of inhabitants