D 6.4 Transferability study

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0 Abstract

The present study regards the possibility of transferring the results obtained during the project 3encult and especially in the Bolzano case study, the Public Weigh House, to other historic buildings.

In case of a single monumental building it is possible to realize profound pre-intervention analysis on a high level of detail, which on urban scale would not be feasible. By precise measurements and analysis of the case study Weigh House it was possible to better understand the characteristics and intervention needs of a certain building type. This allowed us to do diagnosis and to find the right solutions also on urban level for the surrounding buildings by visual inspections, without the use of sophisticated measurement tools and within a shorter time. In a second case, we were able to transfer the solutions for construction details that have been already addressed in case of the Weigh House to another building typology.

The evaluation of transferability of solutions was evolved on two scales:

- **On Urban scale**, investigating the energy potential and defining the possible energy refurbishment interventions for a wide spread medieval building type in the historic city center of Bolzano (Italy), the “Portici”.
- **On Building scale**, supporting the implementation planning phase of the enhancement of energy efficiency of a historic Villa from the middle of the 19th century, near Lake Como (Italy)

In the first case, within the project 3encult, a group of students from the University of Dresden carried out a documentation of this special typology of building, which is characteristic for the original nucleus of the city of Bolzano. Through questionnaires and project plans data on the existing building, the building envelope, the building use and the building energy consumption were collected for several selected buildings of the Via Portici. Complementary an on-site inspection was carried out. This study has been deepened and completed by a team from EURAC by analyzing the energy potential and the intervention needs of this building typology and by assessing the possible implementation of refurbishment solutions exemplary for one “Portici” building.

In the second case the experiences, gained within 3encult regarding the heritage compatible energy retrofit of historic buildings, the development and implementation of technologies and refurbishment solutions within a multidisciplinary design progress, were introduced into the refurbishment design process of a historic north Italian Villa. During four common workshops among the 3encult partner and Bolzano case study leader EURAC and the responsible building owner, architect and energy planner, design steps were discussed and verified and detail connections were evaluated.

1 Starting from the Case Study, the Public Weigh House

First of all, the Public Weigh House of Bolzano in Italy is introduced, which was one of eight case studies within the project 3encult, that has accompanied and stimulated research activities.

Aim of the case study team was to contribute to the diagnosis of this case study, support its design and planning phase and give feedback with its monitoring. At the time of the project, the building was completely uninhabited. The building owner wanted it to become a museum of the photography after its complete architectural and energy refurbishment.

After a comprehensive study on the actual state of the building regarding the construction elements and the determination of their heritage value as well as the assessment of the actual energy performance, a retrofit concept was proposed. All solutions were developed to improve energy performance and environmental comfort while simultaneously conserving the architectural and artistic value of the building elements. The local case study team concentrated on the development of passive solutions that are independent from the building use, as the specific use for the single rooms was still not committed.

For the implementation of refurbishment solutions two particular innovative components were developed. As in this special case a part of windows, which were not of heritage value, should be replaced, the case study team developed, in collaboration with the local heritage office and the project partners, an energy efficient heritage compatible window prototype. A solution for the reversibility of the internal insulation was developed and tested on-site, as well as two solutions for the installation of internal insulation in connection with wooden beam ceilings.

The experiences gained in the attendance of the case study, the proposed refurbishment concept and the technological solutions were then tested regarding their transferability to the buildings of the “Portici” street, a similar medieval building type that surrounds the Weigh House, and to the north Italian Villa Castelli.

In the following chapter after a brief description of the building and its heritage value, the intervention needs and the refurbishment concept, the conclusions for a successful heritage compatible refurbishment of a historic building are introduced.

1.1 Urban context, building history and use

The building of Romanesque origins is placed in the historic city Centre of Bolzano. It is part of the “Portici di Bolzano”, which were built in the end of the 12th century. The “Portici” represent a for this time typical composition of street market with a central grain trade.

The “Via dei Portici” once formed the nucleus of the town. The oldest settlement consists of a road axis along which the constructions of the “Portici” are built on both sides, on narrow and long properties, arranged rectangular to the street. The widespread medieval building type is a house with narrow facades to the street, lined up continuously along the road axis. A characterizing aspect of the “Portici” of Bolzano is the continuous arcade/walkway along the street front. It is noteworthy, moreover, the intensive use of land, which led to a complete use of the property for the construction, not only in width but also in depth - the typical arcade house is four steps wide (not quite 4 meters), 50 meters deep and structured by the atriums into a front, middle and rear house. Through this situation and the serial repetition of this type of building a constant structure has been formed, that is interrupted by a system of atriums for the supply of air and light to the interior spaces. This original, urban system is still perfectly recognizable today. Every building consists of ground floor and usually three upper full storeys, up to three basement floor and an originally non-inhabited top floor. The ground floor was and is used as shopping area. The cellar served to store the goods, while on the upper floors there the living space was situated.

The Public Weigh House is part of the “Portici Street”, but it is separated from the continuous structure of arcade houses on both long sides through a narrow alley. The central part of the building towards the “Portici” and the rear building, as well as the two basement floors are of Romanesque origins of the 12th century. Only afterwards, during the 2nd half of 15th century, the continuous walkway, the arcades, typical for the “Portici” street, were added on the north side. To connect the building to the neighbour building on the west side, during the 1st half of 16th century a bridge over the narrow alley was built. Towards the end of the 16th century, the building has undergone a major intervention, which included among other interventions, the unification of window openings and extensions on the east and west side (over the bridge) of the building as well as the subdivision of the south building part on 2nd floor with interior walls. Several inside partition walls were added during the last century.

Until 1780 the building was seat of the so-called “Fronwaage”, a public officially calibrated town scales. The following history of the use of the building has not been sufficiently analysed so far, but probably, even after completion of the work of the “town scales”, the rooms were used for commercial purposes. In the first half of the 20th century, the building was converted into a dwelling house and only the ground floor was further used for business. Especially after the Second World War the interior rooms have been given new dimensions, there have been installed some partitions to create more dwelling units. Since the 90s of the last century, the house was uninhabited and vacant. In 2009 it was sold by the city of Bolzano to the Foundation Cassa di Risparmio. The purchase agreement states that the property from the first to the third floor and in the second basement floor must be used for cultural purposes for 20 years.

The listed building consists of three full storeys, a top floor and two basement floors. All full storeys and the cellar are built in masonry of natural stones with lime mortar joints. Exterior walls have a thickness of about 60 to 80 cm. All walls (except on basement level) are plastered with lime plaster. Ceilings of the upper floors are built in wooden beams with wooden casing and filling material in between. The underside of the ceiling is plastered with lime plaster. Especially on ground and basement floor, the ceilings are vaulted. The building has a purlin roof with wooden rafters and wooden casing, roofing cardboard (bitumen) on the wooden casing and above it roof cladding with monk and nun roof tiles. In the Public Weigh House, the major part of the original windows, above all on first and second floor, were replaced by box-type windows from the 50s/60s of the last century with an outer an inner sash with single glazing. For shading and darkening, a wooden window shutter is used.

Figure 1 and 2: The Public Weigh House, south façade and fresco ad arc over alley

Figure 3: Fresco on south façade

The local case study team consisted of the European Academy (EURAC) as focal point for scientific support and integrated design process, the "Stiftung Südtiroler Sparkasse" as building owner and the director of the local state office for historical monuments as conservator.

1.2 Structural elements and determination of heritage value

Construction method and heritage value of walls respective internal and external surfaces:

All full storeys and the cellar are built in masonry of natural stones with lime mortar joints. Exterior walls have a thickness of about 60 to 80 cm. The stonework of the walls is covered in most parts (except on basement level) on both sides with historic lime plaster, partially with wall paintings and frescoes. In some parts of the exterior surface, we have facing brickwork; the windows are framed with a profiled sandstone from baroque era. In various rooms, there are stuccoed or vaulted ceilings. To improve the thermal behavior of the external walls, only a (temporary) installation of internal insulation in carefully selected parts of the building is possible. It should be in any case removable and should not leave any trace on the existing walls. The original layers of paint (even if they are not historic), the appearance of the historic plaster, the uneven surfaces and edges should be preserved. The same counts for surfaces with wall paintings, even if paint layers cover the majority of mural painting and only partially visible, they are the most valuable surfaces and should be maintained as they are. The delicate original proportions of the rooms and above all the symmetry of stuccoed ceiling should not be changed by installation of internal insulation. Existing wooden pavement should be conserved.

Construction method and heritage value of roof:

The building has a saddle roof with wooden rafters and wooden casing, roofing cardboard (bitumen) on the wooden casing and above it roof cladding with monk and nun roof tiles. In the current state, the roof construction is partially insulated with a layer of mineral wool of 8 cm to the inside, in between the wooden rafters. The insulation is covered on the below side by a gypsum plasterboard. The roof has to be preserved in his actual form for two main reasons: (i) The Spanish tiles (“Mönch und Nonne”) of the saddle roof are historic tiles. They have a value from conservators point of view because they ´re handcraft manufactured in a unique way. (ii) The homogeneous appearance of the roof scape of the whole historic city centre has to be kept. To assess the roofs not only the visibility is crucial but also the uniformity. Apart from that, the visibility of the roof areas can´t be evaluated standing beside the building and looking to the roof; it must be considered that the whole roof scape of the historic city centre of Bolzano is ascertainable, looking from the surrounding mountains. Not only the appearance of the roofage has to be kept, also the lower side of the roof (down spout) can´t be changed f. e. by rising the roof covering, in case of putting insulation of the roof above the rafters. The profile and the proportions of the roof-edge should be preserved. An insulation from inside is thinkable (insulation in between and below the rafters).

Construction method and heritage value of windows:

The original window used in the “Portici” is mainly a wooden window from the late baroque era. It consists of two window layers, each with two single-glazed window sashes and a skylight. This type of window however has been replaced in many cases by a window with double glazing. In case of the Public Weigh House, the major part of the original windows, above all on first and second floor, was replaced by box-type windows from the 50s/60s of the last century with an outer an inner sash with single glazing. Some few original window are from the late baroque

	era with thin wooden profiles and a single glazing (e. g. in the jutty on north façade). For shading and darkening, a wooden window shutter is used. The windows are framed with a profiled sandstone from baroque era. The showcases on ground floor are single or double glazing from the last century. Most of the frames are thin metal profile frames, partially integrated in the plaster, while the windows in the roof dormers are industrial produced standard insulating glass windows from the 90s. The box-type windows of the 50s/60s are not of historic value. This means that all of these windows could be replaced by a reproduction of a historic window. As there are no documents or information available on the type of the original historic window, the conservator proposes to base the new window on a “classic” window in terms of function, division and proportion. A window with two sashes with two sash bars each sash is recommended. It could be a box-type window, a coupled window or an insulating glass window. In every case, the layer of the outer window should be placed behind the existing historic stone frame. In case of a box-type window the deepness of the box should be similar to the actual windows from the 50s/60s. It should be positioned and installed in the reveal in a similar way. The profiled sandstone around the windows should be preserved. In that cases, where it is a late baroque original window, it should be preserved and repaired and possibly be enhanced from energetic point of view. The showcases on ground floor and the windows in the roof dormers are also not of historic value and could be replaced.

Table 1. Construction elements and description of their heritage values

1.3 Investigation of intervention needs

As conclusion of the pre-intervention analysis and a base for the refurbishment planning the following problems were identified:

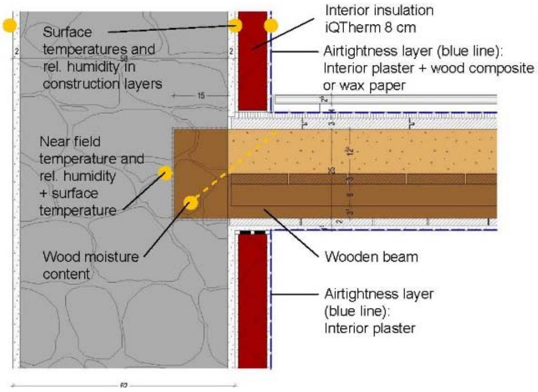
- high transmission heat losses through opaque parts of the thermal envelope and through windows
- high infiltrations respectively uncontrolled ventilation heat losses mainly caused by not tight/leaking windows
- slight overheating in summer, mainly in the south part and on top floor
- lack of daylight, particularly in north, east and west oriented room (towards tight neighboring buildings)
- high relative humidity in basement floors (mold grow risk)
- condensation and mold grow risk in window reveals and weak points of the thermal envelope (putty)

1.4 Description of refurbishment concept

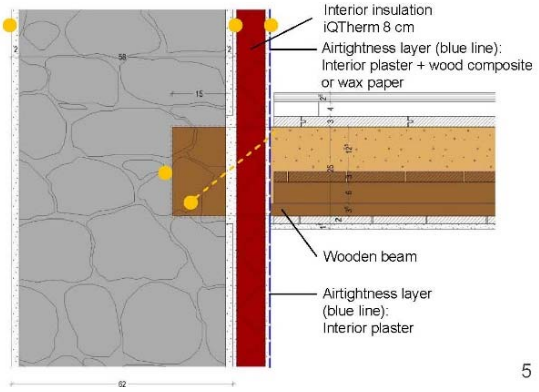
INSUTLATION OF OPAQUE PARTS OF THE BUILIDNG

- **Insulation of walls:** As stated before, the historic plaster should stay the outermost visible layer. Only a reversible internal insulation in some rare, carefully selected, parts of the building is possible.
- In case of the installation of internal insulation, inevitable thermal bridges are remaining in the area where the outer wall is connected to internal construction elements (interior walls and ceilings). The particular difficulty regarding the application of interior insulation in the Weigh House is that the interior floors are built with wooden beams. In case of installation of an insulation, temperatures on the surface (and on the inside) of the original structure are lowered, the wooden beams are then in a cold area, with the risk of condensation at the heads of the beams. It is therefore important to prevent warm moist indoor air, through an "airtight” layer, from flowing to the inside of the structure. It is crucial to "study well the thermal bridge" and to solve the "airtight" connection between internal insulation and wooden beams
- The internal insulation system was realized in a representative “test room” using the capillary active insulation (IQTherm λ = 0,026 W/mK). To realize the reversibility of the insulation layer, the panels are fixed with a clay-based glue, which allows the removal of the insulation also after their installation.
- For the Public Weigh House therefor two possible solutions have been developed, that are transferable to similar wall/ceiling connections. Both executions have been studied with the software Delphin, a simulation program for the coupled heat and moisture transport: one case with an “interrupted” insulation and another case with the “continued” insulation (see scheme).

Version I: „interrupted” insulation



Version II: „continued” insulation



- Continuous airtight layer: internal plaster connected on the upside of the ceiling with airtight horizontal wooden composite through flexible airtight adhesive tape. Downside of the ceiling: Between insulation panel and existing ceiling plaster: compression tape. Continuous airtight layer is here the internal plaster (wall and ceiling)
- Advantages: minimum impact to the ceiling construction, less work
- Disadvantages: thermal bridge in the area of the ceiling, airtightness layer may be

- Continuous airtight layer: internal plaster, which have to be connected with a flexible airtight material all around the wooden beam. In case of cracks in the wooden beam, that pass through the airtight layer, they have to be closed (e. g. by gluing of wooden dowels)
- Advantages: less heat losses, continuous airtight layer
- Disadvantages: connection wooden beams/internal insulation, higher impact on ceiling construction

interrupted at the transition to the next room (interior door).

Table 2. Scheme of wall/ceiling connection with internal insulation

REPLACEMENT/ENHANCEMENT OF WINDOWS AND BUILDING AIRTIGHTNESS

- In an expert workshop the overall window concept for the whole building was developed: for some rare original windows from the late baroque era, it was decided to possibly enhance them from energetic point of view with an additional second window layer, while the box-type windows from the 1950s on first and second floor should be replaced with new windows, which fit better the historic context. The same counts for the showcases on ground floor and the windows in the roof dormers.
- **Replacement of windows:** As there were no drawings from the original historic window available, the new window was based on a “classic” (coupled) window in terms of function, division and proportion, two sashes with two sash bars each. The developed concept separates the demands and functions into two layers: one outer layer for the reproduction of the original historic window and an inner layer for high energy efficiency. In this way, it is possible to obtain the same appearance like the original historic window from outside in terms of frame dimensions, sash bars and mirroring by taking a single glazing, without any negative effect on the energy efficiency. This outer layer takes over the weather tightness. The passive house window with triple glazing is integrated in a second additional inner layer, taking over the airtightness. By rotating the frame cross section 90 degrees and by moving the centre of rotation of the fitting, a smaller frame than the conventional solution was achieved. It is positioned in a way that its frame is not visible from the outside. Following to this approach, both box-type and a coupled window are executable in Passive House window quality. Additionally, it allows also preserving the original old window and just adding the second energy efficient layer (on the inside or also on the outside).

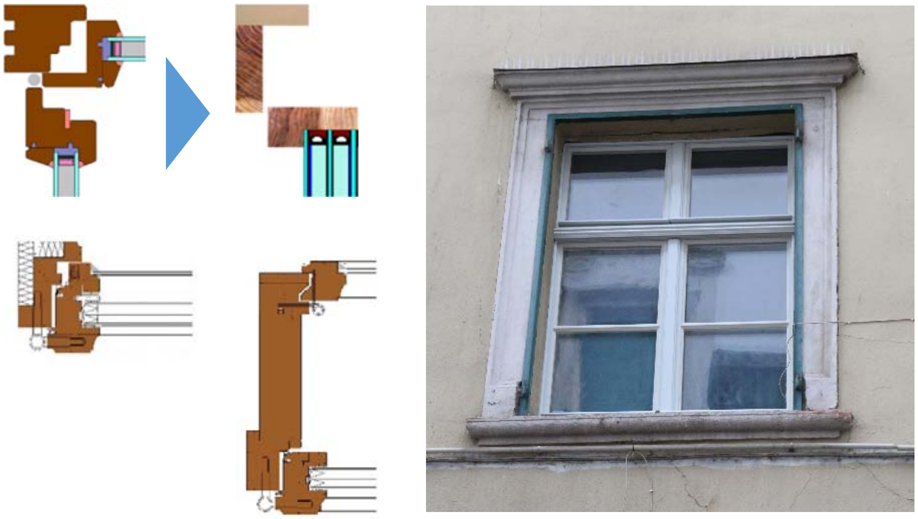


Figure 4-8: rotation of the frame cross section by 90 degrees (fig. 4-5) to achieve a smaller frame; separation of functions into two layers: “historic” window outside, integration of passive house window inside (fig. 6-7), last prototype installed in the Weigh House (fig. 8).

- **Enhancement of windows:** The flexibility of the developed window system allows the integration of an original historic window. In case of the three baroque windows in the putty it is important to maintain the interior view, the additional layer should be added therefore on the outside. For these windows the following solution was developed: removing the existing wooden frame outside, which served for the fixing of the window shutters. Instead of those, provide a second window layer, which takes over the energy efficient function (concept of the composite window prototype “the other way round”). The outer wing can be opened to the outside; it can be executed without the horizontal impost (only one sash). For the other remaining three original windows, instead it was decided to apply the second layer on the inside.

- With regard to the window-wall connection, since in the major part of the case study, no application of internal insulation is possible, the junction was optimised by studying the existing reveal on-site and inserting all around the window an insulation layer of 4-6 cm. This helped two improve the psi-values and thereby to rise the surface temperatures in the critical points to required values.
- Replacing the windows means at the same time a large reduction of infiltration, improving the “airtightness” of the building. In the existing building infiltrations cause a large part of the heating energy demand. With the “air leakage test” it was verified, that (the not well maintained) windows cause a main part of the ventilation heat losses.
- Taking into account the window energy balance (losses minus gains) the net losses can be reduced by 70% (double glazing vs. original window) or respectively 80% (triple glazing). Looking at the total energy balance of the whole building with 14% of window area and walls in natural stones, the exchange of windows can reduce the demand by up to 20%: 10% due to thermal performance increase, 10% due to airtightness improvement (need for indoor air quality considered, without heat recovery).
- U-values existing (box-type) window: Ug = ca. 2,8 W/m²K; Uf = ca. 2,5 W/m²K; Psi installation (without parapet) = 0,238 W/mK; Psi installation (with parapet) = 0,194 W/mK; g-Value = 0,77
- U-values new window after intervention: Ug = ca. 0,57 W/m²K; Uf = ca. 0,97 W/m²K; Psi installation (without parapet) = 0,164 W/mK; Psi installation (with parapet) = 0,124 W/mK; g-Value = 0,44

INSULATION OF ROOF OR OF CEILING OF THE UPPERMOST FLOOR/INSULATION OF SLAB TOWARDS WALKWAY/ARCADES

- Current state of the roof: the top floor is in parts inhabited/heated, the roof is isolated from the inside with a system of 8 cm rock wool covered with plasterboard. In the actual situation the insulation does not fulfil its purpose: it is in parts displaced and there is no “airtightness” layer foreseen.
- **Insulation of saddle roof:** 25 cm of insulation (lambda 0,042), 11 cm between rafters, 14 cm from below.
- U-value existing roof: isolated part of the roof: 1,384 W/m²K (transmittance measured on site); not isolated part of the roof: 2,606 W/m²K
- U-value roof after intervention: 0,171 W/m²K
- Current state of the ceiling over the arcades: Inserted floor ceiling in wooden beams with wooden casing and filling material of sand, earth and little stones in between. The underside of the ceiling is plastered with lime plaster. The floor construction consists of a wooden substructure and wooden boards.
- **Insulation of ceiling over the arcades:** substitution of existing filling material between the beam with insulation (lambda 0,042) of about 18 cm, additionally one continuous layer of 3 cm (lambda 0,042) on the wooden beams
- U-value existing ceiling: 0,437 W/m²K (transmittance measured on site)
- U-value ceiling after intervention: 0,173 W/m²K

INSULATION OF BASEPLATE ON GROUND AND OF BASEMENT CEILING

- Current state of the baseplate on ground: the baseplate on ground is probably a slab in concrete, floor covering in ceramic tiles
- **Insulation of baseplate:** 12 cm of perlite in the pavement structure (thermal bridges caused by interior walls!); (lambda 0,05 W/m²K)
    - U-value existing baseplate: 2,664 W/m²K (transmittance measured on site)
    - U-value baseplate after intervention: 0,36 W/m²K

- Current state of the basement ceiling: the basement ceiling is a vaulted ceiling of natural stones with lime mortar joints, floor covering also in ceramic tiles
- **Insulation of basement ceiling:** 12 cm of perlite in the pavement structure (thermal bridges caused by interior walls!); (lambda 0,05 W/m²K)
    - U-value existing basement ceiling: 1,028 W/m²K (transmittance measured on site)
    - U-value basement ceiling after intervention: 0,297 W/m²K

INSTALLATION OF A CONTROLLED VENTILATION SYSTEM WITH HEAT RECOVERY

- Installation of a controlled ventilation system with heat recovery (efficiency 85%) to decrease the ventilation heat losses. Installation outside the thermal envelope in the basement floor.

The calculation of the heating energy demand shows that it is possible to reduce the energy demand for heating to 50% considering the proposed refurbishment interventions.

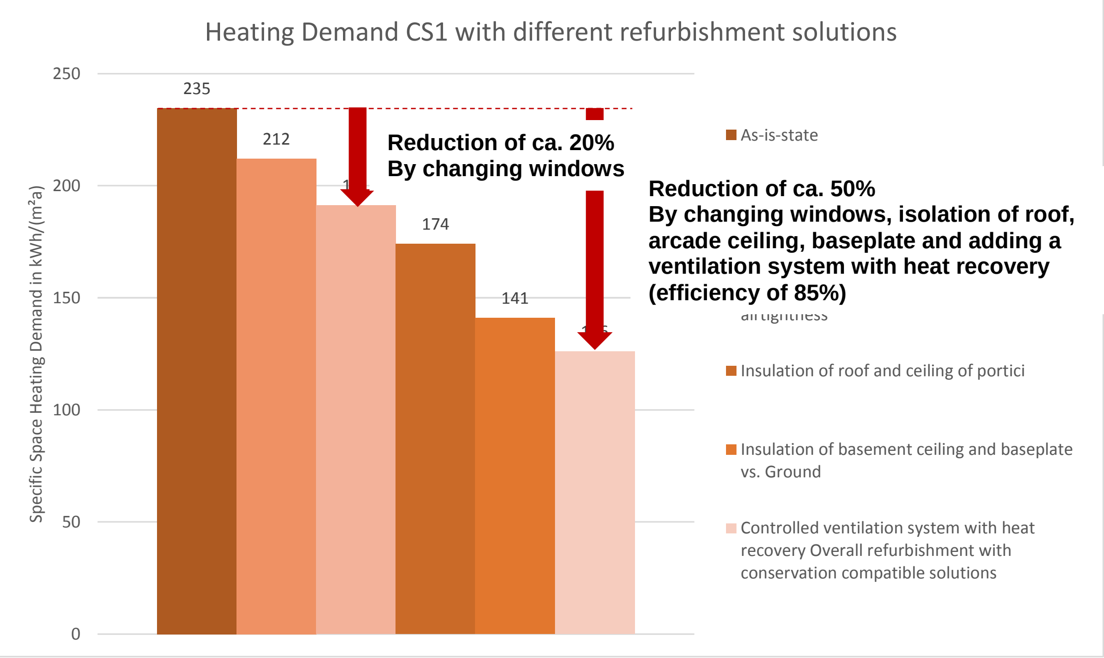


Figure 9: Heating energy demand of Public Weigh House: Reduction of 20% by enhancing the windows, reduction of 50% implementing all heritage compatible interventions

1.5 Conclusions for a successful refurbishment approach

From the attendance the Public Weigh House of Bolzano the following main conclusions can be drawn:

- To include all stakeholder in the design process of the energy retrofit of the historic building.
- For each energy retrofit of a historic building the multidisciplinary exchange between all stakeholders starts with the comprehensive diagnosis of the status quo, supports the development of solutions and selection of the most appropriate one, and does not end before an integrated monitoring and control is in operation, which verifies and guarantees performance
- Comprehensive diagnosis of the status quo include: Pre-intervention analysis such as analysis of historic evolution, investigation of building construction and determination of heritage value of the single construction elements
- Energy performance assessment includes the analysis of physical and mechanical properties of the elements of the thermal envelope, airtightness and infiltration causes, daylight potential, environmental monitoring, assessment of heating energy demand and distribution of heat losses, identification of intervention needs
- Development of a heritage compatible refurbishment concept – an interaction of different passive and active solutions. If needed: development of new products/technologies or respectively adaption of existing products tailored to the individual demands of the historic building. Prerequisites for the development of solutions are:
    - The tight collaboration of planer, developer and conservator from an early planning stage on, that with a sensitive approach, adapt the developed component/concept to the individual case as well as take into account not only the element performance, but also the impact of the installation to the whole building.
    - Starting with the analysis of the traditional (architectural) energy solution of the building in connection with the climate and the use of the building. The recovery of the original energy concept (in combination with new technologies) might allow an energetic and comfort enhancement without compromising the heritage value.

2 Urban level

2.1 Objective

The study aimed to utilize and verify the methodology for assessing energy and environmental quality and, subsequently, for selecting the most appropriate energy efficiency actions in historic buildings developed in the 3encult project. In particular, this method was utilised at district level for the historical centre of Bolzano. The integrated procedure is based on the energy audit scheme, environmental monitoring, comfort analysis and simulation software, in order to individuate the real performances and the technological inefficiencies of buildings, to verify the conservation risks, to preserve the cultural values, to reduce energy consumption and to improve human comfort, health and safety. The study was applied to the buildings of the “Portici Street” in the historic city centre of Bolzano (Figure 10), which represent a typical ancient construction typology.

The study regarded two levels:

- Assessment on district scale to clarity the **potential of transferability**, by evaluation the cultural heritage values and user needs for the buildings of the “Via dei Portici”, (supported by Master´s programme “Conservation and Urban Development” of University of Dresden)
- Assessment of the **energy potentiality** of the historic centre of Bolzano. Representative for all buildings of the Via dei Portici, one Portici building was analysed more in detail (Figure 10).

Figure 10: Via dei Portici with indication of 3encult case study Weigh House (right rectangle) and the exemplary Portici building which was studied more in detail (left rectangle).

2.2 Case study

The city of Bolzano was founded around 1180. It is situated in the heart of the Alps, on the main transalpine route between Germany, Austria and Italy. With at present nearly 100.000 inhabitants, it is the main city of the region of South Tyrol. It lies at an altitude of about 250 m above sea level and has a mild and dry climate. Due to its location in the basin of a deep valley, high temperatures and heat waves affect the city also during summer. The surrounding mountain ranges with a significant height prevent from balancing currents from the north and moisture from the south. This results in a distinctive continental climate with relatively strong seasonal fluctuations, but also daily fluctuations in temperature. In this area, outweigh the west and southwest winds. In winter there is often no wind or wind from north and northeast. Other winds generally are less frequently. The presence of precipitation, more frequent in summer and less in winter, also characterizes the climate.

The original city stretched around “Via dei Portici”, an ancient road of the last decades of the XII Century. The street has a length of 300 meters and it is oriented from east to west in order to ensure the shelter during winter from the prevailing winds, and in summer from rain and sun. Along this street, on both sides, the “Portici” houses are built, a traditional courthouse with arcades lined up continuously along the road axis [3]. The specific construction type of arcade houses is spread over Europe, they can be found from Tyrol over southeaster Bavaria to Bohemia, Silesia and finally to Prussia. On a western rail, they were spread from south France, eastern Switzerland and Westphalia [7; 8]. The houses represent a vaulted archway on the ground floor of the building. This archway in general is part of the house construction, sometimes it was added afterwards. The design has its reason in the optimum utilization of the limited space of the dense city centre. At the same the structures provided protection from sun and rain.

2.2.1 Urban planning

The central street of the mediaeval town, the Via dei Portici, was erected on a gentle slope, since the settlement should be “safe” from flooding. To the south stood of the way two towers and a wall, overlooking a moat. An upper and lower imposing gates (Ober e Niedertor) closed the two ends of the street. A mill was powered by a derivation of the stream Talvera which ran along the southern edge (Figures 11-12). The first substantial modifications to the original configuration were made in 1277 when the walls and the gates were demolished [1] and the ditches filled in. This process continued until the XVI Century with the saturation of the lots and the consequent construction of new sections of buildings alongside, that in some case are completely independent from the existing building stock (Figure 12-13).

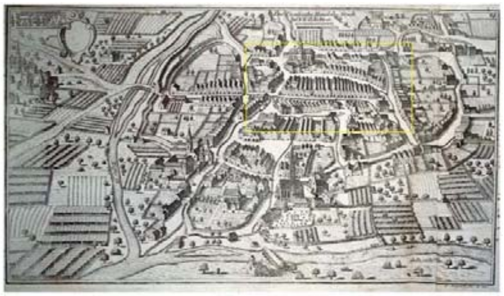


Figure 11. Map of Bolzano, 1700 – 1766 (From Gabriel Bodenehr)

Figure 12. Cadastral map of “Via dei Portici” in Bolzano, 1858 (From Autonomous Province of Bozen)

The need to avoid major modification in the natural lie of the land and to minimize the effects of the wind imposed an east-west axis on the alignment of the buildings (Figure 13).

Figure 13. Urban structure of Via dei Portici (Elaboration of the Authors from Autonomous Province of Bozen)

A characterizing aspect is the continuous arcade along the street. In truth, the line of the buildings has never been continuous because to limit the effects of the high number of fires, the covered walkway and façade was broken into three sections. The arcades, together with the basement, formed an extension of the houses for purchase and sale. In the beginning, the site was not completely covered with buildings: at the backside were situated enclosures for the livestock and a small horticulture area, in direct contact with the city walls. Initially, the buildings had cross sections from 8 to 12 m, appropriate for ensuring the natural air and light and the comfortable temperature.

The more recent buildings were constructed with two or three blocks interspersed with inner courtyards (atrium) to ensure the necessary natural light and air into the interior spaces. The serial repetition of this type of building has been formed a constant structure, interrupted 3-4 times by a passages (Figure 16) that conducted in the parallel streets [4].

Figures 14 and 15: “Via dei Portici” in the centre of Bolzano (From Authors)

Figure 16. Passages in the “Via dei Portici” in the centre of Bolzano (From Authors)

2.2.2 Historic buildings

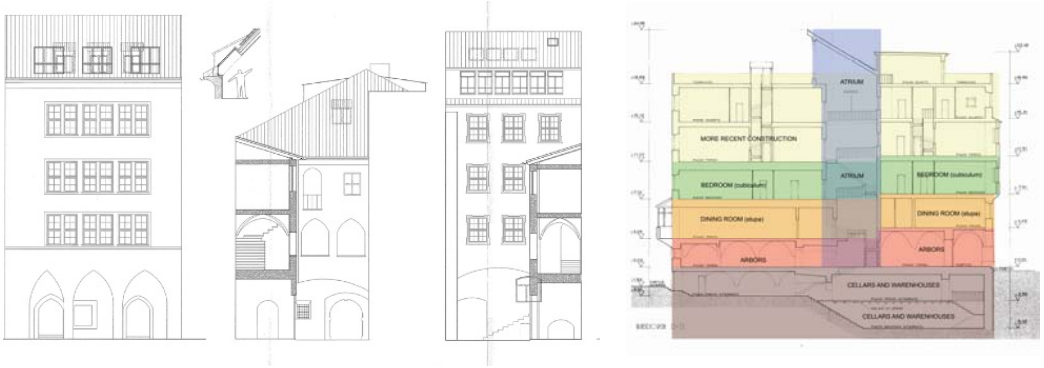
The original typology of the “Portici” Houses acted together dwellings, workshops and warehouses on one parcel. The inhabitants were merchants or artisans. Lying rectangular to the street, which passes from east to west, the buildings are north-south oriented, thus every building has a north and south façade. Today the eaves side of the roofs are orientated to the street. But originally (see in Figure 1), the houses were positioned with the gable facing the street. To lead away the raining water, small eave alleys were situated between the single parcels. These is still can recognizable, sometimes overbuilt, in the small passes leading from the Via dei Portici to the parallel streets.

Shape and dimensions

The houses are built according to a particular pattern, called “gothic deeper lot”, which provided façade with limited and constant amplitude. The length of the houses depended on the needs. The limited space forced to very narrow façade, which are often only two or three windows wide, but extend in depth and include regularly two or three atriums. The typical arcade house is four steps wide (not quite 4 meters), 50 meters deep and structured by the atriums into a front, middle and rear house. The original surface-to-volume ratio (S/V) ratio of the arcade houses was very low. The compact shape aimed to decrease the heat losses through the building envelope and, simultaneously, to maximize the internal volumes.

Internal distribution

The primary houses with porch, in Romanesque style, consisted of ground floor and usually three upper full stories, up to three-basement floor and an originally non-inhabited top floor. The internal floor exploited well the building physics: orientation and internal functions of the rooms are designed to take advantage from the principles of heat transfer and environmental factors. To create a filter zone with a thermal protection, in the lowest floor are inserted the natural heated rooms. The basements were an extension of the shop on ground floor level and were used as magazine to store goods. On the ground floor, are located the shop and the kitchen, which heated the upper floors with a fireplace (only the wealthiest families also had a fireplace in the first floor). In the upper level are located the rooms with the permanence of people that, where possible, are oriented towards south to capture the solar radiation in winter. A wooden staircase connected to the first and the second floor, which housed respectively the dining room (*stupa* or *stube*) and the bedroom (*cubiculum*). In the bedroom are used the blankets (*coltra*) and the furs to heat up. Originally, the top floor was not used and worked like a thermal buffer (Figures 17-18).



Figures 17 and 18. The "Portici" House in XII Century (From Historic Archive of Bozen)

The rooms are positioned according the occupancy and frequency of use: rooms with less frequency of use or need of daylight (i.e. bathrooms or kitchens) are located in the inner part of the building, around the atria. The more representative and larger rooms (i.e. living space, trading rooms) are located towards "Via dei Portici" while the rooms with less importance (i.e. storage) are in the central and back part of the building.

Atria

As mentioned above the depth of nearly every house is interrupted by two or three atria. The staircases and open passageways are situated here. The courtyards have two functions: they provide the internal rooms with daylight and fresh air. The stairwells are vaulted to protect from direct rain. Usually, the vault is open to the side of the wind incidence, to ensure some cooling at high summer temperatures.

Constructive technologies

The cellar walls are built in masonry of natural stone and lime mortar – not plastered. The foundations are founded directly on the soil and the floor consists of tamped earth. Because of its contact to the surrounding soil and its depth of 6 m and more, the internal climate of cellars is quite independent from the external climate. The basement walls are double-walled: ventilation passages enable the supply of fresh air and keep the cellar free of mold. The constant cool temperatures provided an ideal condition for the storage of food. The ground floor are built of masonry of natural stone and lime mortar. Masonries, ceilings, and roofs are thought for preserving the heat produced internally. Originally, the first floor was made with wooden beams. Because of frequent fires, also this part was been built in natural stones (rough calcareous stone) and lime mortar (XIII Century). Exterior walls have a thickness of 60-80 cm. All walls (except on basement level) are plastered with lime plaster. The openings are small to avoid losses and increase thermal insulation. The original windows didn't have the glazing, as they were too fragile and expensive, but only external shutters in wood and curtains. They were added in the XVII Century. The original window was a wooden box-type from the late baroque era. It consists of two window layers, each with two single-glazed sashes and a skylight. Ceilings of the upper floors are built in wooden beams with wooden casing and filling material in between. The underside of the ceiling was plastered with lime plaster. The floor construction consists of a wooden substructure and wooden boards. Especially on ground and basement floors, the ceilings are vaulted. The construction of the saddle roof is made in timber rafters with wooden casing and roof tiles on it. The roofs met the needs of climate protection from cold, wind, rain and snow. The specific conformation with two or more layers ensured the same conditions of insolation to each sloping. The inclination of the roof is quite high due to snowfall and rainfall. It is designed also to allow the formation and the maintenance of an additional "snow cover" which ensures thermal insulation of internal spaces.

2.3 Changes in the energy concept

2.3.1 Urban planning

The urban structure has remained almost unchanged over the centuries. The differences are related to the widening of the historical centre around the historical core. The major changes have been made between XVI and XVII Centuries, when the block was completely filled with buildings [4; 7; 8]. Subsequently, there have not been more significant urban changes with an impact on the climate (Figures 19-20).

Figure 19: Map of the city, 2011 (From Autonomous Province of Bozen)

Figure 20. Comparison between map of the city 1858-2011 (From Autonomous Province of Bozen)

2.3.2 Historic buildings

The buildings, visible today in the forms assumed in the XVII and XVIII Centuries, retain the original medieval structure. The major changes were made in 1950 [4], when the original energy concept was modified with the closure of atria, the use of the top floors and the construction of dormers.

Shape and dimensions

Compared to Romanesque typology, the houses have more raised floors. This causes the change of the surface-to-volume ratio, while the porosity (ratio between full and void volume) remains almost unchanged, maintaining the good cooling conditions of the building. The slenderness (ratio between volume and average surface) increases.

Internal distribution and distribution

Than in the past, the commercial functions on the ground floor have remained unchanged while the layout of the upper floors has been completely changed. The functions are no longer just residential, but also tertiary and commercial. The main entrance still opened out onto the street, while the secondary entrance exploited the alleyway flanking the first block. Access to the third block was directly from the lanes running along the back, constructed after the ditches had been filled in. In short, the changes regard: increasing of the volume (multi-family dwellings), stylistic features, internal layout and construction materials. The modifications merged with the existing, becoming imperceptible precisely they represented continuity with the old. The cellars are used now either for storage, but often also used as showrooms (by covering the stone masonry). This means a massive installation of lighting, cooling and heating, with a negative impact on the energy consumption. During the new paving of the Portici Street the ventilation slots were closed with concrete, so that causes several problems of humidity and mold growth in the cellars. Also, cellar and ground floor are not climatically separated by shops and this cause a higher condensation risk of warm and humid air on the cold surfaces of the cellar walls.

Atrium

In the XIX Centuries, the top openings of the atria have been additionally closed, often repeatedly on the level of different stories. For the closure mostly glass canopies were used especially at the roof level, but often also within the court. In rare cases, there are intermediate canopies from an alternative material (Figures 21-23).

Figures 21-23. Closure of the atrium with canopies, doors and windows (From Authors)

The closure cause a lower air circulation and overheating during summer. In general, are utilized several outdated technologies to improve air changes. These are often no longer functional or too loud to use them. The glass canopies also no longer meet their original purpose: they are not easily accessible and often uncleaning from outside. For this, the insufficient incoming daylight is problematic in many narrow and deep atrium.

Constructive technologies and plant

From the constructive point of view, walls have not undergone major changes. The bearing structure have remained unchanged, while the other walls were demolished to make room for larger rooms. In most cases, now the top floor is habited, losing the original buffer function. There are original windows only in very rare cases: they have been substituted by industrial produced windows with double-glazing. Today, the upper commercial and residential units often have a decentralized boiler in combination with radiators, while the shops usually use no heating system. High internal gains/loads, caused by non-energy-efficient lighting, and the clothing of customers make a heating system unnecessary. To compensate possibly temperature differences during winter and especially to cool the rooms during summer, electrical air conditioners are used. The units on the upper floors usually don’t have any cooling system.

2.4 Master’s programme Conservation and Urban Development

2.4.1 Description of the Masters programme

The post-graduate Master`s program was established in the winter semester 2003/2004 at the Technical University of Dresden. The aim of the programme was to convey practical knowledge and skills as well as the scientific basis necessary for professional work in the fields of conservation, sustainable urban development and cultural resources management. Emphasis was put on the development of a theoretically and practically competent, future-oriented approach to historic buildings, cities and cultural regions, giving special consideration to the role and development of their functions under evolving cultural and economic conditions.

The responsible bodies of the program were the Chair of Conservation and Building Research, the endowed Chair of Urban Development and Urban Studies as well as the Center of Expertise in Urban Regeneration Görlitz.

The special profile of the Master’s program was its interdisciplinary approach. The historic preservation focuses attention on the valuable historical heritage and its conservation for the public benefit. Historic preservation includes the identification, investigation, evaluation, conservation, restoration and sustainable management of cultural assets and sites. For sustainable urban development the question is paramount, how the urban habitat can be usefully preserved and developed. Knowledge in scientific methods of urban research, conceptual urban designs, historical and current factors of urban development and strategies were provided to the students.

Students were trained in developing strategies for the successful preservation of cultural heritage and the further development of the European city. Thus the graduates are highly experienced for a professional activity in offices for urban planning, architecture, landscape architecture, historic preservation and building research, in public authorities of building preservation and urban development, in teaching, in research institutions or in relevant oriented professional fields of business, administration and media.

The Master's Program Conservation and Urban Development was closed with the winter semester 2012. By decision of the Council of the Faculty of Architecture, no new students were matriculated from 2011. The small study groups required high support costs, which in turn allowed an intense and multifaceted study. The Faculty Council considered the shutdown of the Master’s program as the only way to acknowledge the mandatory saving targets as they were defined by the University.

2.4.2 Curriculum content

The designated period of study was four semesters. In the first two semesters the scientific background and practical basics were provided. The third semester was a project semester, divided in three practice-based projects. In a first step the students had to analyze a certain urban district, the second period was used do work out developing plans with special focus on several requirements. In the third project part students had the choice to deepen the work of the second project period or even to choose another task according to their own interests. The forth semester was designed to write the Master thesis.

Course Content

- historical and theoretical basics of conservation and sustainable urban development
- scientific and practical working methods of urban studies and urban design as well as methods and techniques of conservation
- Factors of urban development in the national and international context
- Theory and practice of conversion, conservation and development on urban level in terms of future problems and solution strategies
- Protection, mediation and sustainable management of historic sites,
- Communication and presentation skills, team-and results-oriented work, task management
- Interdisciplinary development of solutions

- Projects with partners from practice (Application and Research)

2.4.3 Organization of project work

A student group from the Master`s program on Conservation and Urban Development was supposed to perform an exemplary study on transferability of the experience at the CS 1 Weigh House to other buildings and quarters. The students work was as sub-project 3 part of their project semester of the Master`s program and contained the practical work on location and a written elaboration.

- Duration of the practical work on location in Bolzano: 1st to 8th of March 2012
- Participating students: Alexandra Rumanovska (written elaboration), Bianca Brümmer, Sabrina Smelz
- Responsible lecturer: Franziska Haas (TUD)

In a first step the students had to analyze the Weigh House regarding its historical and architecture historical background. On base of literature, sources of local archives and on-site inspection the historical development and typical elements of the “Via dei Portici” in general and in particular for the Weigh House were described. On base of this historical investigation the group carried out a documentation of the special typology of building, which is characteristic for the original nucleus of the city of Bolzano. For selected parts of the Weigh House itself was required a documentation, containing a “roombook” (cultural heritage aspects) and a photo documentation as well as the determination of cultural heritage values. Finally the students were supposed to work out suggestions and guidelines for a refurbishment of the Weigh House and to give recommendations for the transferability to other building in the Bolzano city center.

2.4.4 Realization

Regarding the prominence of the historic center of Bolzano with the Via dei Portici, it was surprising that there were only few scientific works about the building type of arcade houses. Hannes Obermair and Helmut Stampfer published an interesting contribution on the origins of the medieval town center of Bolzano, but the paper covers only the time before the big changes during the Renaissance. And indeed, good documentations for individual buildings exist, but an architecture historical context involving other examples in Europe is still missing. Some basic statements can, however, be given:

- Arcade houses are a typical construction type for dense inner cities
- The design with the partial superstructure covering parts of the street allows a higher space utilization of the expensive downtown land
- Due to its location and construction the houses are mostly used for trade
- Since the formation of arcades is not climate-related, the building type is spread over Europe

A task for the students was to examine the potential for transferability of well-done refurbishment solutions to other buildings in the center of Bolzano. A survey was organized to the buildings of Via dei Portici, partly leaded by Waltraud Kofler Engl form Cultural Heritage authority, to find answers to the following issues:

- How were the buildings used in the past? Distribution of the functions, typical use of the arcade houses (originally and today)
- How was the energetically behavior of the building originally? How is it today (were functions changed or overbuilt e.g. closing the opening above the stairwell / courtyard)
- Documentation of architectural features that could be energetically used:
  - Documentation of the potential for passive heating: solar gains through windows, possibly geothermal over basement
  - Documentation of the potential for passive cooling: natural ventilation, night ventilation, cooler zones (basement)

- Building constructions and used material
- Features of particular interest for cultural heritage preservation

On base of the survey, the references from the literature review and the information by local experts building elements could be defined, which may be regarded as typical for the arcade developments. The analysis was performed with a special focus on building climate relevant components. But the students recognized that the buildings parameters not have the sole influence on energy demand. On the basis of the historical architectural analysis, a questionnaire was worked out by the students. This was addressed to the residents and users of the buildings and should determine the "perceived" need for rehabilitation and satisfaction in dealing with the buildings. By visiting the arcade houses have occurred following common points:

- Almost all the houses in the street and on the parallel roads are in a reasonable condition. However, they were mostly renovated in the 1960th and 1980th. The former interventions do not meet the today’s requirements anymore.
- Each house is divided into commercial and residential units. This requires special measures, particularly for the shops
- The basement can be used either as a warehouse, but also often as sales rooms. This means massive installation of artificial lighting, which results in a negative impact on the energy costs.
- The constant temperature in the basement areas can be described as positive. Therefore they have to be not or only slightly heated.
- In almost all cases the stairwells are subsequently covered, often several times. Mostly glass canopies were used - especially at the roof level, but often also within the court. In rare cases, the intermediate canopies are of different material or even not exist. The closed atriums lead to a poor air circulation and enormous heat in the summer months.
- The ventilation system in the stairwells are mostly outdated and often not functional or too loud for the operation
- The cleaning of glass canopies is partly not possible, resulting in a decreased incidence of light
- The energy costs for heating and cooling are perceived by users as being too high.
- In every store one or more air conditioners and heaters are available. The installations vast space and are expensive. In the apartments, this problem is not so pronounced

In addition, information about the status of restoration was collected, because even these may result in conclusions for transferability study. It involved investigations to windows, roofs and plasters as well as changing in use of the buildings.

2.4.5 Conclusions

The students were able to show the current state of knowledge about the construction of the arcade buildings as well as the associated refurbishment objectives. The results of the entire survey are incorporated in the present investigation here. A special contribution to the development of the project the students could give with their self-initiated user survey. This has driven the focus from a purely buildings-related consideration towards the involvement of user interests.

2.5 Study of the energy potential

The study regarded the energy audit, the analysis of the users' comfort, the environmental monitoring and the verification of the structural problems in one exemplary building of the Portici street. The analysis could be applied in others building of the "Portici" street.

2.5.1 Aims

The method of diagnosis is devoted to evaluate energy and environmental performances of historic buildings, in order to define the most appropriate retrofit actions. An accurate audit is the first step to identify the need for suitable intervention. This means understanding the original construction, the alterations, the actual conditions, the qualities, the material and the immaterial values, the lacks, and the retrofitting opportunities. The evaluating method consists of the following phases:

- Assessment of architectonic, historic and aesthetics values;
- Energy audit based on relief, documentary research and non-invasive tests;
- Evaluation of human comfort and indoor performance of the building;
- Definition of the suitable retrofitting actions.

The analysis of the historic urban planning and the historic building is very important to understand the original energy concept and the changes that have occurred. In the case study, the biggest problems are due to the alteration of the original energy concept. Therefore, this knowledge has been central for defining the most compatible retrofitting solutions. For this reason, project plans and historic data were collected for several selected buildings. Subsequent, a residential and commercial building was subjected to a more detailed investigation, considering energy audit and comfort analysis techniques. The energy audit is a method for collecting, gathering and evaluating energy performances and saving of buildings. It is very important for individualizing the inefficiencies and the malfunctioning. The study is also supported by the analysis of users' comfort and profile of use of the building, obtained with questionnaires and interviews conducted using the Post Occupancy Evaluation method. Finally, were defined the energy efficiency measures most compatible with the features of the historic building and the needs of the comfort.

2.5.2 Description of works

Energy audit

During the general study of the Portici houses, a very often repeated statement concerned the high cost of energy for heating and cooling. To illuminate, heat or cool the vast spaces especially of the shop areas is very costly. In our particular case, the annual calculation for heating from energy bills showed a comparatively low energy consumption (Figure 24).

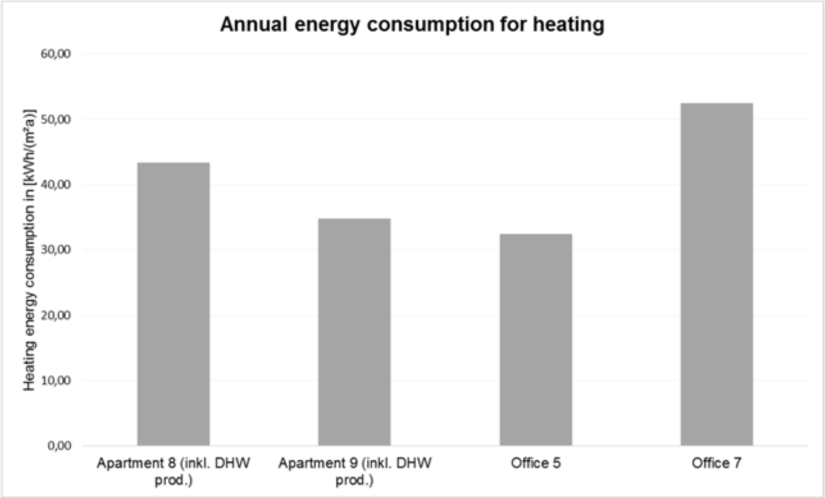


Figure 24: Annual energy consumption for heating in different units

The annual energy consumption for heating varies from around only 32 kWh/m²a to around 52 kWh/m²a. This is due to the fact, that in the year 2000 the thermal transmittance of the envelope of this building has been improved by insulating the roof construction and substituting the composite windows from the 60th with new double glazed windows. Furthermore, the storage of heat in the thick wall construction allows switching on the heating system comparatively late in autumn. The users heat up during the day only the main rooms of the offices or apartments and switch off the heating system during the night. Anyhow, energy consumption for cooling and lighting the shops remains high.

Users' comfort analysis

All inhabitants of the 11 commercial and residential units participated in a user survey and an on-site inspection. Aim of this inquiry was explore the perception of the visual, thermal, hygrometric and olfactory comfort in the indoor environment, considering the impact of the outdoor condition. Additionally, a checklist gave answers about the users' behaviour (i.e. frequency and duration of natural ventilation, moisture, occupancy times and overheating). In addition, structural problems were verified like humidity or mould and what users would suggest to improve the quality of living in this house. It was used the traditional method proposed by the standard UNI EN ISO 7730 (2006) to predict the actual climate sensation of persons: a 7-point psycho-physical scale with values ranging from -3, indicating cold, over 0, indicating neutral, to +3, indicating hot. The interviews showed that users are quite satisfied with the internal comfort in general. The supply of fresh air is evaluated as sufficient while the supply of daylight is sufficient depending on position and orientation of the rooms. There is a lack of daylight inside the building and in the spaces towards the atria. This is due to the change of use: now there are also office rooms with a higher demand for lighting (Figure 25). Furthermore people feel disturbed by noise particularly from the street (people, musicians, delivery of goods), when they keep the windows open. The energy costs/benefit ratio is evaluated very differently – some users perceive it as low other as much too high. In general, people are quite satisfied with the life quality in a Portici House.

(At the end of the document, please find one exemplary questionnaire attached)

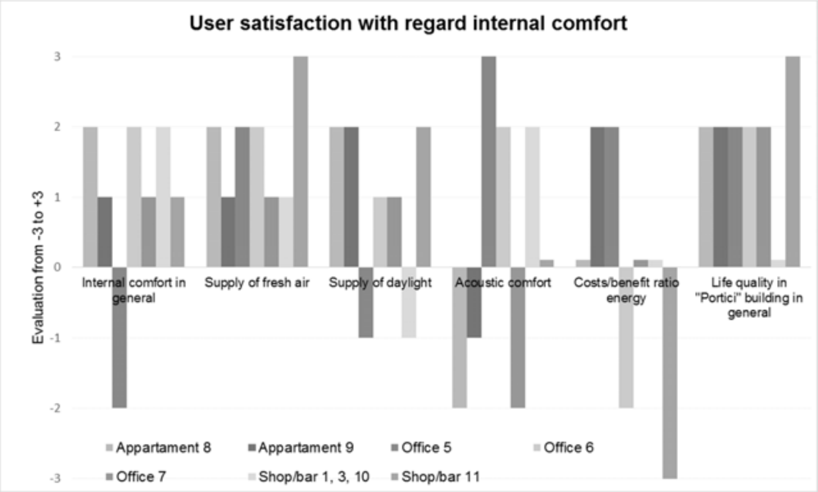
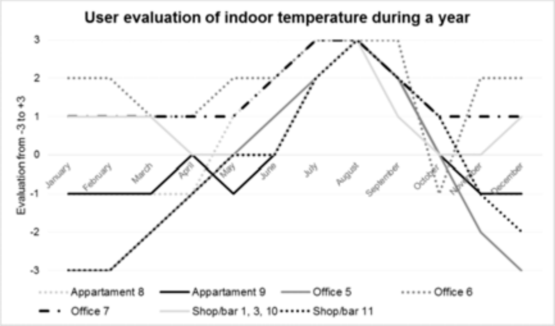


Figure 25: User satisfaction with regard internal comfort

Specifically, the indoor temperature was evaluated. During winter, the assessment is not uniform, depending on settings of heating system, physical activity and use of the unit as well as the personal perception, the interviewed people felt from "cold" (-3) to "warm" (+2). During summer, there is a tendency towards overheating about 3-4 weeks (Figure 26). The relative humidity was considerate quite comfortable. Only in winter, some people consider the clime dry and in summer wet (Figure 27).



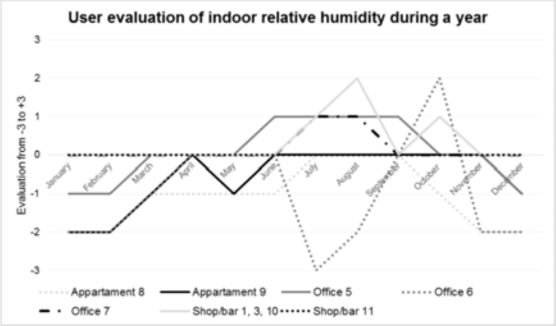
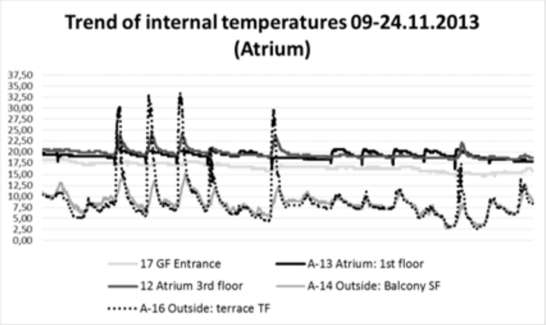


Figure 26: User evaluation of indoor temperature during one year

Figure 27: User evaluation of indoor relative humidity during one year

Environmental monitoring

To substantiate the user evaluation of comfort, we carried out a monitoring of the indoor climate. On two different days, we measured in the main rooms the indoor comfort in terms of temperature, relative humidity, CO_2, air speed and luminance in a raster of one by one meter. Additionally we recorded the indoor air temperature continuously for 14 days in the key rooms (e.i. kitchen, living room, sleeping room) of every unit. In parallel, also the trend of the outdoor temperature and the temperatures at different heights in the atrium was recorded. In the atrium the temperatures are very high, probably due to the presence of glass canopies (Figure 28). In the studies and the apartments the temperature are lower, with a good stability due to the presence of heating systems (Figure 29).



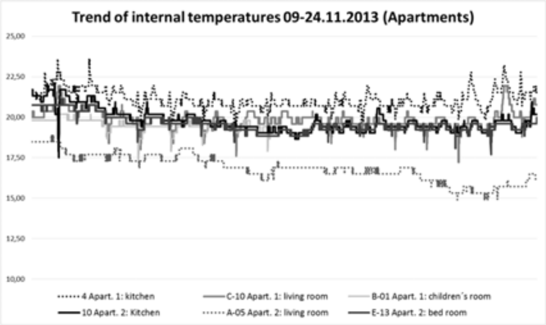


Figure 28: Trend of internal temperature in the atrium

Figure 29: Trend of internal temperature in the apartments

On-site lux measurements, obtained in a static way (at a single point in time), confirmed a punctual daylight factor in the different room lower than 2.0%, which would be the minimum value to guarantee an acceptable supply of daylight. The daylight Factor is a ratio that represents the amount of illumination available indoors relative to the illumination present outdoors at the same time under overcast skies. It determines the quantitative characteristics of daylight in a particular workspace, in order to verify if a room has sufficient daylight.

Verify of structural problems

Almost all the houses of the Portici Street and the parallel roads are in an acceptable condition. Most of them were refurbished and adapted to new functions and housing demands during the centuries and therefore interventions do not meet the latest requirements. One of the few structural defects, which were mentioned in the survey, are moisture problems in the basement rooms. The fact that heated rooms on ground floor are no longer climatically separated from the cellar rooms, allows the humid warm air to pass into the cool basement rooms and to condensate on the cold wall surfaces. In addition, inadequate ventilation of the basement rooms exacerbates the problem.

2.5.3 Energy retrofit solutions

The energy efficiency retrofitting of the Portici Houses may include the internal insulation of walls, floors and roofs, the upgrading of the performances of windows and the selection of high efficiency boilers. Many of the Portici houses have historically and artistically very valuable paintings or decorative elements on the inside surfaces and on the facades. This excludes in almost all cases interventions on the walls: insulation is therefore not possible. The internal insulation of roofs is also possible. The replacement of windows can be reached by different interventions according to their historical value. First, it is necessary to preserve, maintain and upgrade the historic windows. When they have to be replaced, hand-crafted wooden windows possibly also with handmade glass are preferred, in order to come closer to the original appearance of the house. In the building analysed, all these interventions have already been made, except the isolation of the slab over the arcades. Therefore, are proposed other innovative solutions, departing from the discovery of the original energy concept.

Hybrid natural ventilation

Stack ventilation is one of the most effective and reliable methods of driving natural ventilation for atria and adjacent spaces. It is proposed a hybrid natural ventilation strategy: a system where natural ventilation is promoted whenever the outdoor air temperature is lower than the atrium air temperature and kept air-tight, whenever the outdoor air temperature is higher than the atrium air temperature. This strategy may be implemented using a set of temperature controlled motorized louvers installed at the ground floor of the atrium that open and close the doors at fixed time. Another cooling strategy will be studied in detail: to exploit the low internal temperatures of the basement stores during summer. In this case, the base will not be ventilated and must be climatically separated from the above floors. A ventilation system with a recovery unit exchanges and cools down the supply air of the upper floors with the cool air from the “cooling reservoir” of the cellar.

Shading

Some of the Portici houses have traditional shading elements. The traditional design of these shading elements are wooden shutters with adjustable slats. Many of the houses anyhow do not have a shading system. Often the high-decorated façade and the small distance between the windows in the façade makes the use of wooden shutters impossible for technical and for conservation aspects. In these cases, the integration of a modern shading device into the window system, that would also meet the aesthetic demand from conservation point of view, would help to avoid high indoor temperatures during summertime.

Optimization of daylight

To improve the supply of daylight especially in the inner rooms of the building, old chimneys or chambers that have no function anymore, could be used to redirect light (as solar tunnel). Depending on the orientation of the chimney, to bring down the daylight from the roof into the depth of the building, a main mirror has to be installed on the roof (heliostat system). The existing chimneys serve as a vertical channel to transport the sunlight: over mirrors in these chimneys an over openings toward the rooms the light is reflected and distributes into the rooms. In addition an enhanced daylight autonomy would be desirable. This could be achieved by the integration of daylight redirection system into the window and shading system. Wall surfaces should be coated with bright wall paint to reflect the incoming light in a better way.

Lighting

The substitution of the lighting systems in the shops and restaurants with high efficient illumination like LED systems would be a very effective measure to reduce energy consumption significantly and to reduce the risk of overheating during the summer season.

Integrated PV

The heating of the outdoor spaces of the bar is obtained with infrared lamps. The systems, used also by the historic Marketplace of Piazza delle Erbe, have a high energy consumption. The intervention may design an integrated photovoltaic shelters thought for the centre of the town, in order to preserve the heritage value and to reduce the energy consumption for heating. Similarly, on existing roofs is possible to predict reversible and integrated PV tiles because the Heritage Office don’t exclude this. To affect less the appearance the use of solar films is a viable alternative.

2.5.4 Results of the energy simulations

All energy calculations of the exemplary Portici building have been done with PHPP (Passive House Planning Package). PHPP is originally an energy calculation tool for the planning, verification and certification of Passive Houses. A new feature, which has been developed within the 3Encult project and integrated into the general version of PHPP, allows designers to verify the energy demand in modernized historic buildings or other refurbishment projects [1]. The calculation of the actual annual heating demand (after refurbishment of the building in 2002) with the PHPP software results in 94.5 kWh/m²a (1).

Energy simulation for original as-is-state

For the simulation of the original as-is-state (before refurbishment 2002) we assumed coupled windows (U_g: 2.8 W/m²K; U_f: 2.5). With this simulation of the example building we wanted to assess the heating energy demand representatively for that part of the Portici buildings which have not been refurbished so far. Most of them have either coupled or box-type windows with two single glazing. We further assumed that the top floor ceiling is the uppermost part of the thermal envelope since originally, the roof was not isolated and the top floor was not inhabited. According to these parameters, the calculated energy demand for heating is **137.0 kWh/m²a**.

The simulation shows the distribution of heat losses: one fourth is lost by the ventilation heat losses. That means uncontrolled air leakages of the thermal envelope. Over the exterior walls (incl. the wall towards the open atrium) and the windows, we have transmission heat losses of about 25% each. Another 11% of the heat losses is transmitted over the exterior walls towards the closed atrium. The rest of heat losses is transmitted over the top floor ceiling (7%), the baseplate (baseplate on soil and basement ceiling) (6%) and the ceiling above the arcades (1%), (Figure 30).

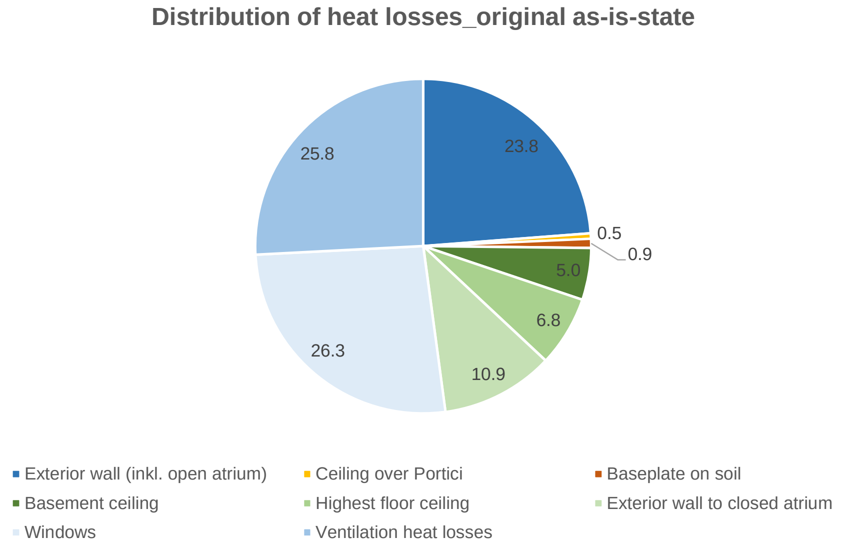


Figure 30: Distribution of transmission and ventilation heat losses

It is notable that comparatively little heat is lost over the top floor ceiling and over the ceiling above the arcades. This is due to the fact, that the ceiling construction in wooden beams with wooden casing and filling material of earth, sand and little stones in between has a comparatively low heat transfer coefficient of 0.44 W/m²K. Furthermore, heat losses over the windows are relative high as the area of transparent surface of a Portici building is quite high compared to other mediaeval buildings of this climate zone. The transparent surface area of the facades is more than one third of the total surface.

Energy refurbishment in 2002

During the refurbishment of 2002, the windows were exchanged (U_g=1.1 W/m^{2}K), the roof was isolated with 16 cm of wood fiberboard and high efficiency gas boilers were installed for every unit: heating energy demand **94.5 kWh/m^{2}a**.

Figure 31-32: Windows used in the building

Passive refurbishment solutions

The numbers of the distribution of heat losses (above) show were to do the most efficient interventions in the Portici houses: the improvement of energy performance of existing historic windows with heritage compatible solutions or the exchange of existing windows, which are not of historic values, has a high effect on energy demand of the building. At the same time, the intervention on the windows cause also the improvement of airtightness of the building. To improve the energy performance of the opaque parts of the thermal envelope, we suggest isolating the roof and the ceiling over the arcades. From heritage point of view, these are all interventions that do not affect the heritage value of the building. In case of improving the energy performance of window, heritage compatible solutions have to be developed hand in hand with the conservator. Because of original plasters, frescos and decorations neither external nor internal insulation is advisable. To decrease the ventilation heat losses additionally a controlled ventilation system with heat recovery could be installed (Figure 33). With the implementation of all suggested interventions an energy reduction of factor 2 is possible to **53.6 kWh/m^{2}a**.

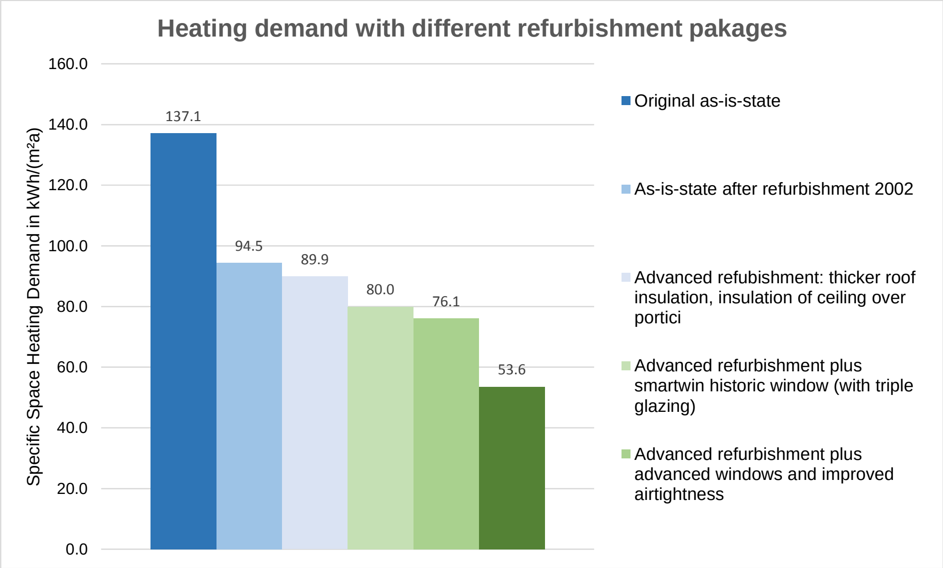


Figure 33: Considering all the listed interventions an energy reduction of Factor 2 is possible.

2.5.5 Conclusions

The updating of old centres to adapt to contemporary societies requires the attention to sustainability criteria and environmental issue, both at urban and building scale. In historic houses, the recovery of the original energy concept permits to reach together comfort standards without compromising the heritage value. In the “Portici” houses, the major change has been made since the Fifties. These modifies apparently are made by imperceptible measures that are completely indifferent to the original physical structure and responsible of numerous negative alterations of the fabric. Related to energy bills and comfort analysis, a correct project should reduce the heating losses and increase the solar gains. This requires the improvement of thermal resistance and airtightness of the envelope and the guarantee of daylight and natural ventilation. For this, atria are key elements for a holistic refurbishment of the buildings, in order to develop hybrid and natural ventilation, daylight redirection, control of solar gain and discomfort glare. Also, the lighting project of stores, shops and bar requires the replacement of existing energy sources with more efficient systems that allow space heating. Finally, the PV integration may be studied at urban level, obviating to the problems of compatibility and reversibility with the historic building.

3 Villa Castelli (Lake Como)

3.1 Objective

Objective of this study was the accompaniment and validation of the planning phase of an energy refurbishment project for a single historic building, called Villa Castelli. The chosen residential building lies near the Lake Como (Italy), near the village Bellano. The project is noticeable on one hand for the historic and architectural value of the building and on the other hand because of the willingness of the building owners to realize a radical energetic refurbishment of the thermal envelope and the building services, by at the same time preserving its architectural features.

The ambitious objective of the building owners was to renovate the building, which had belonged to the family for about 140 years, maintaining the original use of the single rooms in a way without excessive changing and making the building habitable in its entirety, even at a time, in which, to maintain the level of comfort, which we anyhow now are used to, the operating costs would become consistently less sustainable.

It was therefore necessary to develop a project to improve the energy efficiency in a way to obtain the best possible results with three basic constraints:

- act by means of heritage compatible intervention
- keep the budget under control
- achieve the lowest possible operating costs in future

Figure 34-36: Lake Como, the village Bellano and the case study seen from above (Google Earth)

3.2 Case study/the project team

The project team was composed of different stakeholders which contributed within a multidisciplinary working progress to the definition of the goals and to their achievement:

- **Architect and building owner:** Valentina Carì: team coordination, architectonical project, construction supervision, all phases of commissioning, consulting on restoration issues
- **Structural engineer:** Vincenzo Buizza, “Studio di Ingegneria Tecnica”, static consolidation of existing structures with interventions which allowed the conservation of the unique architectural character of the building
- **Energy-efficient refurbishment project:** Oscar Stuffer, “Solarraum”, energy concept, detail planning of thermal envelope and building systems, energy calculations
- **Scientific support:** EURAC, consulting and validation of project work, verification of construction details from building physics point of view, control of calculations, development of a monitoring system (for “post – evaluation”)

During the project process and the development of solutions, several workshops were held either on-site or as phone conference. Each solution has been examined several times and improved through the collaboration of the multidisciplinary team.

The ClimaHouse Agency (the regional institution for energy certification of buildings in South Tyrol) has considered this building as a case study for the validation of the calculations and of the certification procedures, related to the energy certificate for refurbishment of existing buildings (CasaClima R).

3.2.1 History of the building

The Villa Castelli was built in the agricultural land around Bellano, near Lake Como, in the second half of the 19th century. A first portion of the building complex was part of a group of buildings used for agricultural purposes. These buildings were often decorated with wall paintings. Indeed, the oldest part of the Villa Castelli has paintings most likely dated back to this period. A picture which was taken around 1870 shows the oldest part of the building adjacent to another rural building, decorated in neo-Gothic style.

Figure 37: Print showing the village of Bellano (Falkeisen 1838)

Figure 38: postcard from Bellano 1906, in the foreground the “Cotonificio Canton”

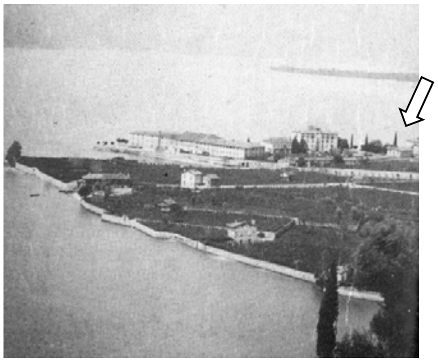


Figure 39: The plain of Coltogno at the end of the 19th century, Villa Loreti/Castelli on the right (Mezzera Collection)

Figure 40: The villa "Pensa" with the buildings of "Sosta" in the foreground (Monti-Bertarini-Vitali "Un paese del lago" Mazzotta, Milan 1982)

The cadastral map, realized under Austrian domination between 1840 and 1855, already shows the extension shape of the future building, which was probably under construction at the time when the maps were created. The old part of the building has been probably joined to the new one, through the existing arbor stable. The Villa owner was Dr. Lodovico Loreti, a doctor and director of the local hospital, opened in 1908.

Figure 41: Cadastral map excerpt Lombardo Veneto, 1840-1855 (state archives of Como)

Figure 42: Aerial surveying September 1988 (municipal archive)

Before he moved to Como, he sold the Villa to Emilio Giosuè Castelli, who used the Villa during summer vacations. In the following decades the Castelli family modified the building according to their needs. They first enlarged the ground floor and then increased the building height to relocate other floors.

Figure 43: House of Dr. Loreti (Bertarini-Vitali "Un paese del lago" Mazzotta, Milan 1982)

In 1925 a substantial renovation of the facade with etched plaster lent the building its coherent architectural appearance: The complete architectural shape of the building was made consistent with a renovation of the facades, by changing the old large windows on ground floor into new slimmer and thinner windows, using recurring architectural elements, colourful frames, pillared balustrades, façade decorations with plaster treated with “sgraffito” technique, which gives the facades its peculiar characteristic.

During the digging out for the new baseplate, some new facts about the building story were discovered: the original ground floor was lower than the one after the renovation. It was assumed that the reason for this are the frequent lake overflows. Thanks to the water regulating measures, nowadays, since many years no building flood occurred anymore.

A last relevant enlargement occurred in 1939, during the Second World War, before the Castelli family was forced to move from the building permanently. They added a veranda with a dining room and they installed a heating system with radiators probably powered by some stoves.

In the following years, only heating system generators and furniture were changed.

Figure 44-46: the Villa Castelli with its garden, the gate to the lake and the entrance way









Figure 47-49: decorations on the façade
Figure 50-52: window typologies
Figure 53-55: decorated interior doors

3.2.2 Historic evolution of the building construction

The first demolitions of the plaster, during the refurbishment works, made visible different building construction elements which reflect the historic evolution of the building.

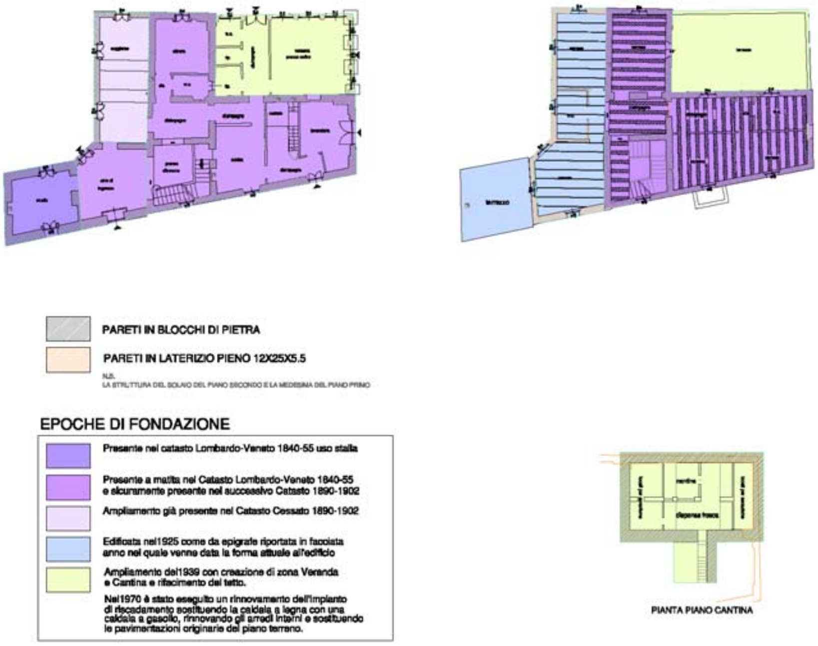


Figure 56: The building phases of the various portions of the building

The oldest main walls of the building are 42 cm and 62 cm and made of local natural stone. The first building enlargement was constructed in brick walls and the following building elevations were built in perforated bricks.

The slabs had different architectural characteristics depending on the construction period. The ceilings, dated back to the late 19th century, are wooden made with dry floor covering. Also steel structured ceilings with brick filler and steel structured ceilings with concrete slab were found.

The roof had a primary and secondary wooden structure with roof tiles laying directly on the structure.

The presence of construction elements from different historic times forced the designers to define a significant number of structural joints. Detailed simulations supported the design team in order to choose the most effective solution able to lower the effect of thermal bridges. Several wall typologies were tested by simulation to reduce material thickness at the minimum needed, by at the same time facilitating the execution phase and avoid installation errors.

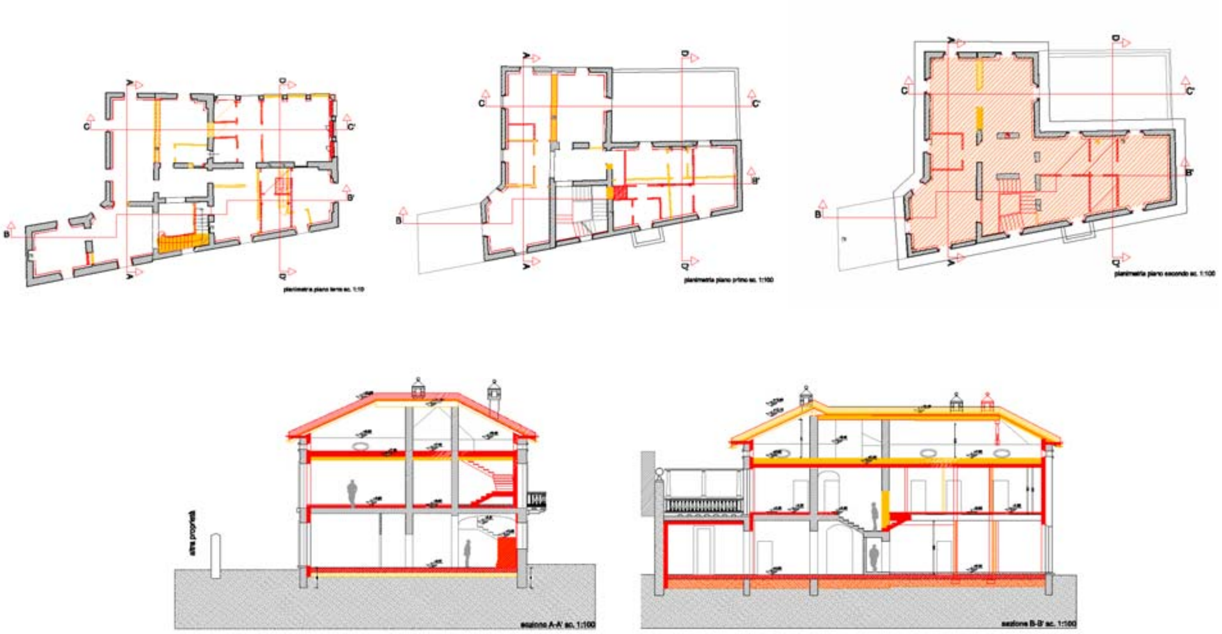


Figure 57: Floor plans of ground floor, first and second floor, and sections (demolition in yellow and new construction in red)

3.2.3 Heritage compatible refurbishment of the building

The case study building is constrained by superintendence of architectural heritage, therefore both the urban and the building development in the area is limited.

Facades/Internal insulation:

The appearance of the facades should not be changed from conservator´s point of view. This constraint, in addition to the beauty of the exterior surfaces, which were still very well preserved, were the base of the decision for an insulation on the inner surfaces of the exterior walls. In this way, although being aware of the difficulty to avoid thermal bridges, a conservation compatible solution for the opaque parts could be found.

The internal insulation of the exterior walls has followed the criteria to standardize the thicknesses of the insulation layers. A difference has been made in the area of the veranda in order to not alter the very thin architectonical shape: while the majority of the walls the insulation is of 20 cm perlite, in the area of the veranda, it was planned to cover the pillars of reinforced concrete with a high-performance material with reduced thickness, such as aerogel.

A very substantial part of the work has focused on the restoration of the facades. It was based on a careful analysis of the state of conservation and an exchange with the conservator about suited restoration techniques, materials and colors. We started with a general cleaning of the facade with traditional restoration techniques. All structural cracks were sealed with a special kind of lime based mortar. The micro cracks were sealed with the introduction of silicates by the use of syringes. The surface plaster was consolidated with a filling of silica materials. The intervention, which was conducted by a team of specialised restorers lasted more than two month and was stopped because of the lower temperatures. The work will be continued with the restoration of the hoof on ground floor and the repainting of the plaster in the area of the veranda.

Room layout:

The refurbishment project does not foresee changings of the original intended use of the historic room layout as a form of respect towards the history of the landlord´s family, who has owned and used the building for a long time. Therefore the position of the main elements and room functions like e. g. the kitchen, the stair case and the entrances has not been changed. The changing of room functions that have been foreseen, were simply to correct the defects of the existing room distribution, due to the fact that the building is the result of several successive enlargements and that it was not born as one uniform architectonical element.

Sealing:

A primary need was to find a solution for the problems related to the position of the building at the edge of the lake. It is located on a sandy soil and is affected by the phenomenon of capillary moisture. In particular in the area of the ground floor there was made a cut with a chemical barrier by injecting at high pressure a micro emulsion of concentrated silicones. This intervention was carried out a year before the actual start of the work. By lowering the level of the existing ground level inside the building, it was possible to construct a ring of consolidation, in terms of a foundation concrete slab connected to the external walls.

The stratigraphy of the floor has been studied in order to obtain a continuous moisture isolation with the cut made in the exterior walls. A waterproofing membrane posed on the foundation concrete slab will be folded in correspondence of the wall until overcoming the level of damp, thus avoiding the ascent of moisture by capillary action through the external walls.

Within this resulting vat will be placed XPS panels with a thickness of 20 cm, on which the heating plant will be installed.

Statics:

The only bearing wall that has been demolished, was the one that divided the two building areas which were constructed at different epochs and which have a difference in room height of 35 cm. It was created a portal of steel placed on beams. In order to discharge the existing wall from above loads and demolish it, a steel portal frame has been created and bound to the (foundation) beam at the base of the wall. Extraneous elements and flooring were removed from the upper wooden floor. After this, the floor has been reinforced with steel connectors that join the wooden beams to a concrete layer reinforced with welded mesh.

The ceiling of the highest floor was lowered by about 35 cm, by adopting a light and thin solution out of laminated wood in connection with a cast of compensatory concrete. The constructed ceiling has a total thickness of 17 cm, it is anchored to the exterior walls with steel shelves, which were designed to limit the linear thermal bridge. This intervention has allowed the re-use of the attic-space, formerly used for the servants and later converted into a store.

In particular, it was decided to carry out several static consolidation that support the existing structures without destroying them. In certain cases, if activation of storey collapse mechanisms occurs, specific reinforcement systems will provide the necessary static support.

After the removal of the existing roof, a curb of reinforced concrete on the upper end of the wall has been realized in order to better distribute the loads of the new roof. This expedient makes the structure more rigid thanks to the ring shape. The building is now static consolidated both at the bottom and at the top. The new roof is provided with a concrete eave, whose reinforcing bars are anchored in the curb.

Roof:

The building owner wanted to modify the roof in order to have a smoother surface that eases the cedar needles (of the near cedar tree) to slide down. After a long discussion with the conservator it was decided to change the roof tiles with a double metal sheet, similarly to the roof covering of coeval buildings. To achieve a visual separation between the restored existing part and the new roof covering, the eaves inserted were made of concrete.

The roof has been completely replaced with a new structure in laminated wood, with a package of insulation of 42 cm, consisting of cellulose fiber, wood fiber and rock wool. A system of “false” rafters around the eaves allowed to limit the aesthetic impact of the thickness of the roof, that from outside the roof border has the same appearance like the original situation.

The roof skin, double-crimped aluminum sheets, is very light and thin. It will host a mono-crystalline photovoltaic plant, with a thickness of few millimeters. This solution was approved by the conservator as a perfectly integrated element.

Building services:

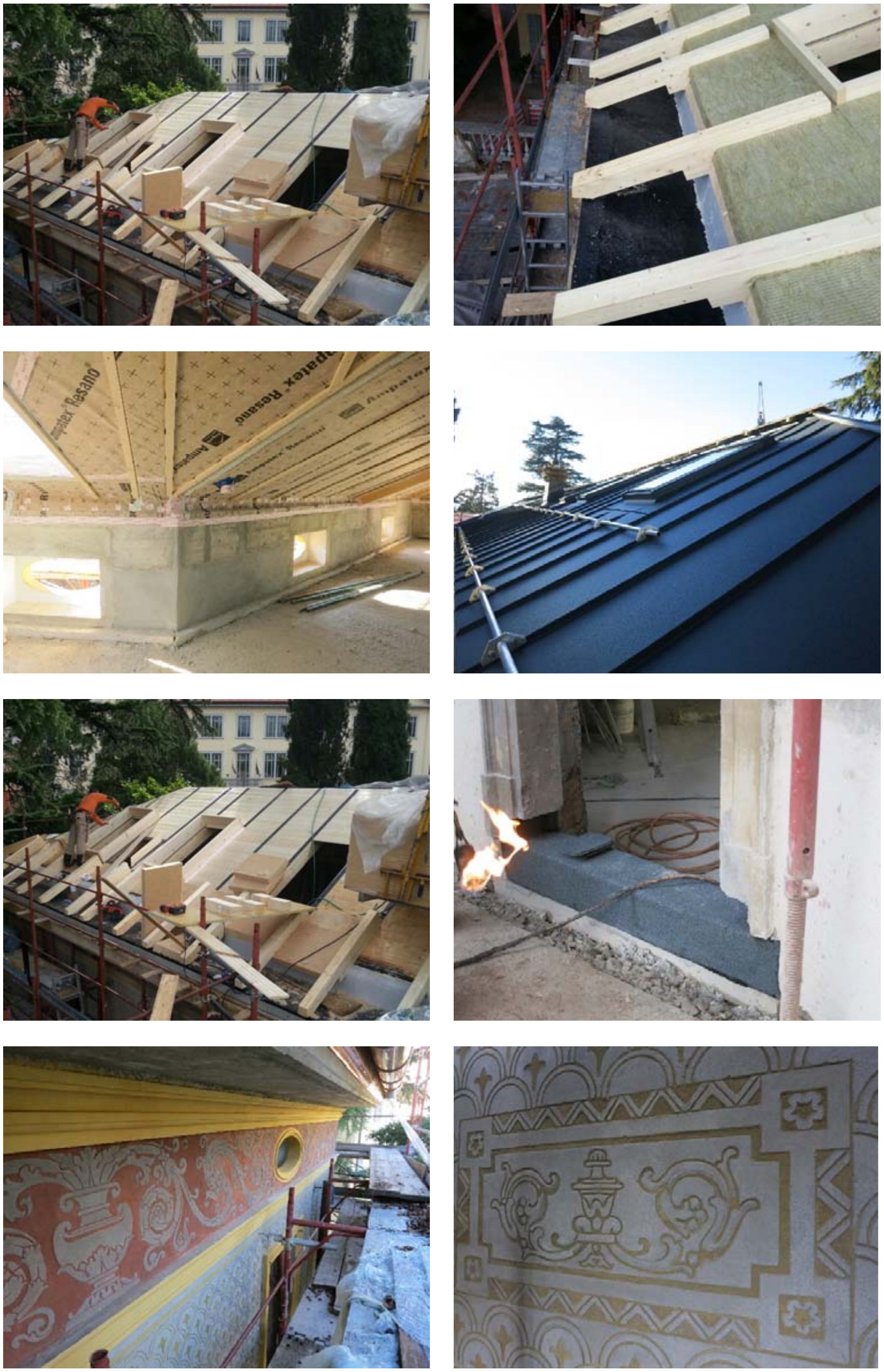
The building plants have been studied in order to be able to subdivide the interior spaces in the future in to three different units. They were optimized therefore for a subdivision into the different building floors.

Decorative elements (inside)

The interventions foresee also the repositioning of all decorative interior elements such as doors, window frames, chimneys etc. This with the aim to bring back the building to the original appearance it had in the decades immediately after the Second World War.

Figure 58-64: Work on the construction site

Figure 65-72: Work on the construction site



3.3 Energy retrofit

3.3.1 Objectives

Prior to the beginning of the planning phase the objectives of the building owner with regards the target for energy efficiency were clearly defined:

- Implement an overall energy refurbishment, acting on the entire building and its building services
- Aim to minimize the overall energy demand
- Compensate the remaining energy consumption with an on-site energy production by installing a photovoltaic plant and small wind turbine on the roof
- Possibly produce energy from renewable sources

The building should thus be possibly self-sufficient from energy point of view. All with a particular attention to the budget, which the building owner managed and controlled personally.

3.3.2 Boundary conditions

The basic boundary conditions were already very challenging. In connection with the objectives of the building owner they increased the complexity of the project. The building is defined in the Master Plan as a monumental building and garden. As it is part of the “Galasso” Ley, it is protected by heritage office. This means that from the outside no changes to the building can be executed unless a minimum and that interventions related to the installation of solar panels and other sources of energy supply would be difficult to implement.

To reduce the losses due to transmission, it was therefore not possible to apply a thermal insulation from outside. Thus the solution focused on the analysis of the application of an internal insulation. In addition the building is affected by the movement of groundwater and therefore rising damp, as it is located near the lake of Como. In order to apply any type of thermal insulation, any danger of infiltration into the thermal insulation system had to be withdrawn.

In this concrete case, a horizontal cut over all existing walls that are in contact with the ground was chosen, using the injection technology. This application is very demanding, since a large part of the walls is made of stones and of a high thickness.

The building was built and expanded several times in its history. Each extension was executed using materials and technologies that at that times seemed to be appropriate. This fact made an intervention very challenging, given that the solutions that had to be analysed in detail were multiplied for the different situations found during the process of verification of consistency. There was for example not only one construction detail for the connection of the wall to the window frame, but depending on the time of construction this node has been planned differently to optimize the correct installation of the window and therefor to reduce the Psi-value of the wall-window connection.

Regarding the climate conditions, there are 2.383 heating degree days, 183 heating days and an average outside temperature during the heating period of +8°C, a standard outside temperature of +5°C. During the summer, due to the position over the lake with its winds, the heat is less perceived, even if the monthly average maximum monthly average temperature is +27°C.

3.3.3 The as-is-state of the building

As mentioned above, the building was built, depending on the construction period, with walls in natural stones, brick, or concrete, a roof in wooden structure and slabs and ceilings of different construction methods.

The ceiling above the veranda towards the balcony was built with steel beams with a slab of concrete. Especially this slab had a much accentuated deformation, which caused consequently greater difficulties for the application of thermal insulation aligned with the ceiling.

The building has three full storeys with a gross heated surface of 680 m², a net heated surface of 564 m² and a gross volume of 2606 m³. The opaque elements have a surface of 1273 m², while the transparent elements are 86 m². The S/V ratio is 0.49.

3.3.4 Pre- intervention analysis

The verification of the status of the building consistency was fundamental to be able to judge:

- The state of construction (static, moisture, cracks, etc.)
- The stratigraphy of the individual components
- The constructive nodes

Its knowledge is the pre-requisite to able to analyse afterwards:

- The actual energy performance of the building
- The interventions for improving energy efficiency
- Possible new stratigraphy
- The solutions of the construction nodes by applying energy efficient interventions

3.3.5 Energy concept

Since the objective of the building owner was to have possibly a self-sufficient building from energy point of view, the energy concept had its primary objective, to reduce the building´s energy demand to a minimum (thermal insulation of the thermal envelope, replacement of windows, installation of a controlled ventilation system with heat recovery). The remaining energy consumption was covered by renewable energy sources (geothermal probes with heat pump), while the self-production of energy was covered by an integrated photovoltaic system and a small wind turbine on the roof.

3.3.6 Analysis of the actual energy performance

The energy analysis have been performed with the software of the ClimaHouse Agency of Bolzano (ProCasaClima 3.2).

The calculation of the actual energy performance shows the following results:

Average U-value of the thermal envelope	1,74 W/m²,K
Energy gains and losses related to the position of the building	
Transmission heat losses during the heating period	126.389 kWh/a
Ventilation heat losses during the heating period	18.487 kWh/a
Internal gains during the heating period	8.676 kWh/a
Solar heat gains during the heating period	6.583 kWh/a
Relation between heat gains and losses	11
Energy demand and thermal output	
Utilization degree of heat	0,98

Heating demand for heating during heating period	129.922 kWh/a
Heating power	63,33 kW
Specific heating power referred to the net surface area	112,20 W/m²
Heat demand for heating referred to the net surface area	**230,19 kWh/m²a**
Efficiency of the building thermal envelope according to ClimaHouse	**G**

3.3.7 Energy analysis: Variants and final results

The analysis approach included the verification of various variants, of interventions with quality levels and of different single stratigraphy.

The following list presents the results of the variant that was going to be implemented:

Average U-value of the thermal envelope	0,26 W/m²K
Energy gains and losses related to the position of the building	
Transmission heat losses during the heating period	18.723 kWh/a
Ventilation heat losses during the heating period	10.723 kWh/a
Internal gains during the heating period	8.676 kWh/a
Solar heat gains during the heating period	4.937 kWh/a
Relation between heat gains and losses	46
Energy demand and thermal output:	
Utilization degree of heat	0,98
Heating demand for heating during heating period	16.104 kWh/a
Heating power	12,87 kW
Specific heating power referred to the net surface area	22,80 W/m²
Heat demand for heating referred to the net surface area	**28,53 kWh/m²a**
Efficiency of the building thermal envelope according to ClimaHouse	**A**

Through refurbishment interventions the heating energy demand can be reduced from 230,19 kWh/m²a to 28,53 kWh/m²a. The reduction of the heating demand is -87%.

The above reported results have been achieved through:

- Insulating the exterior walls with 20 cm with thermal insulation (perlite)
- Insulation the roof with 18 cm and 14 cm of cellulose wood fiber
- Replacing the existing windows with new windows in wood (Uf=1,20W/(m²K), Ug=0,70 W/(m²K), g-value=0,45
- Isolation of the floor against the ground with 20 cm of XPS
- Installing a ventilation system with heat recovery (one unit per floor)

3.3.8 Critical issues

The most critical points of the project were:

- High thickness of internal insulation: here the section has been verified with dynamic calculations of the moisture/vapour transport
- The remaining thermal bridges which for various reasons were not solved:
    - For architectural reasons (e. g. where it was not possible to reduce the clear passage width)
    - For structural reasons: on the new ceilings in wood, where the thermal cutting was not possible to execute completely
    - For structural reasons: the wooden beams that lay before and after the refurbishment on the existing masonry and passing therefore through the entire layer of thermal insulation
    - For reasons of space and cost, for example the connection parapet of window/thermal insulation of wall
- Being a refurbishment of a building built in different construction periods, even if a very precise analysis of the status quo and also a precise detail planning had been made, the unknowns during the execution are many. We searched the optimized solution between conservation aspects, energy efficiency, risk of thermal bridges, technical feasibility and cost of the single interventions/solutions.

3.3.9 Building services: as-is-state

The existing heating system, which had been implemented during the last extension of the building, consisted of an oil burner that produced heat for the radiators and the hot water. The historic heating system consisted of stoves in stoneware in different zones of the building, to heat the single rooms.

3.3.10 Building services: installation project

The new plant was designed as a system that reduces the ventilation losses during the winter period: a ventilation system with a heat recovery unit on every floor. Its other important functions are to control the air humidity in the rooms, given that the building is lying in a zone closed to the lake and to guarantee a controlled supply of health and clean air, because of the high airtightness, that the envelope will have after the complete refurbishment.

The production of heating and cooling and hot water is supplied by a heat pump with a geothermal plant (probes). The heat for heating and cooling is distributed to the rooms through a radiant floor system. It must be emphasized that the specific power of cooling will be very low, to not degrade the wooden floor and structures.

The production of energy on site will be carried out through a photovoltaic system on the roof, integrated into the sheet of metal of the roofing, in a way that it is not visible from outside. Being a very special plant, the project is still in working progress. As well as that of a small wind turbine for the production of electricity. Also that is positioned on the roof.

3.4 Workshop 3encult

The workshops held among the 3encult partner and Bolzano case study leader EURAC and the responsible building owner, architect and energy planner, aimed to support the implementation planning phase of the refurbishment project. The experiences, gained within 3encult regarding the compatible energy retrofit of historic buildings, the development and implementation of technologies and refurbishment solutions within a multidisciplinary design progress, were introduced into the refurbishment design process of the historic Villa. During four common workshops, design steps were discussed and verified and detail connections were evaluated from energy and building physics point of view. Finally a monitoring layout was developed to measure the quality of the refurbishment project “post-intervention”.

3.4.1 Aim and content of workshops

Workshop 15/11/13: Introduction of the project, internal insulation of external walls and insulation of baseplate

Among: Architect (Carí), energy planner (SOLARRAUM), scientific support (EURAC)

First section and second section:

The first workshop served to understand the actual condition of the building, the intervention needs and the state of the refurbishment project. After the explanation of the historic evolution of the building, its architectonical characteristics and the original construction materials, used in the different construction phases of the building, the participants worked out the heritage value of the single building elements and respectively the constraints from conservation point of view. By means of project plans the so far planned refurbishment interventions and all related relevant construction details were discussed. Photos showed the working progress on-site: in detail the structural work of consolidation and the horizontal sealing of the exterior walls and ground floor pavement was discussed.

The interventions on the opaque part of the building were discussed: The exterior wall will be insulated with a 23 cm thick layer of perlite panels (lambda = 0,042). In the area where the outer walls are connected to internal construction elements (interior walls and ceilings) can remain therefore inevitable thermal bridges. The thermal bridges can lead to an increase of heat losses. At the same time the installation of interior insulation leads to reduced temperatures of the inner surface (in the structure; or on the original structure) and therefore to damages caused by condensation. On the basis of the project plans the participants identified all critical connection details, with the aim to optimize them from energy point of view and to avoid condensation problems, if necessary, simulating the heat-moisture transport in the construction. Especially for the following joints, a verification was needed: sealing at the bottom of the exterior walls, several different window/wall connections, partially in connection with raffstores (at veranda), ceilings/wall connections, especially those with existing wooden or metal beams lying in the wall construction and interrupting the insulation layer.

For the existing stair, which was immediately adjacent to the stone wall, it was already foreseen to remove it, in order to pass with a continuous insulation layer behind the stair on the inside of the wall. The original stair will be reinstalled after the intervention.

In the area of the bottom of the exterior walls the existing interior and exterior plaster has been knocked off because of rising moisture. It has been replaced with lime plaster.

The beam ends of the wooden ceiling on the north side of the ground floor has been partially opened, to visually verify their conditions. The bearing wall has been originally an exterior wall in the area of the formerly not covered veranda. It was therefore exposed to direct weathering and the beam ends could have been damaged by entered humidity from outside. The exemplary opened beam ends were in a good condition and therefore all beams were maintained without any interventions.

Workshop 21 and 22/11/13:

Among: Architect (Carí), energy planner (SOLARRAUM), scientific support (EURAC)

First section (21/11/13):

EURAC presents experiences and results from other projects: in case of a refurbished orangery in Bolzano, where also internal insulation with high thicknesses were applied to stone walls, the long-term monitoring of the material layers at critical points confirmed that there was no accumulation of moisture in the construction. The solution for the window/wall connection of the case study Weigh House is explained: since in the major part of the case study, no application of internal insulation is possible, the junction was optimised by studying the existing reveal on-site and inserting all around the window an insulation layer of 4-6 cm. This helped two improve the psi-values and thereby to rise the surface temperatures in the critical points to required values. EURAC underlines the importance of optimizing the window installation situation for building physic reasons and shows how high the impact of heat losses at the window/wall connection on the energy balance of the whole building can be.

Second section (22/11/13):

Two main critical points are discussed: the sealing at the bottom of exterior walls and the installation of internal insulation in connection with existing metal and wooden beam ceilings.

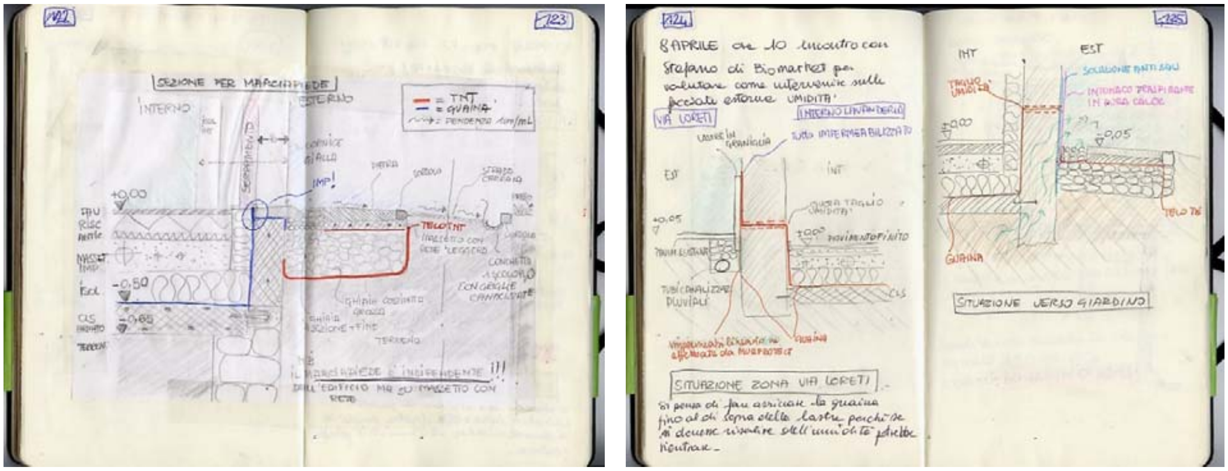


Figure 73: Documentation of 2nd Workshop: Optimization of the sealing at the bottom of exterior walls

Solution for sealing at bottom of exterior walls:

The exterior walls have been sealed, injecting at high pressure a micro emulsion of concentrated silicones into regular drilled holes at a height of about 0,5 m above the interior floor level. The horizontal sealing of the baseplate was then pulled up on the interior sides to the level of horizontal cut in the exterior walls. It is important that humidity that enters from outside, has the possibility to get out or respectively to dry out towards the exterior side. The construction must be therefore diffusion open. EURAC recommends to pull up the inner sealing another 0,5 m over the horizontal cut in the exterior walls to avoid that entered water from outside over the horizontal layer tries to dry out towards the inside. The added vertically sealing on the inside helps to “point the way” for the entered water to dry out towards the outside.

Solution for metal beam ceiling:

The solution for the airtight connection between the penetrating metal beams (double-T-girder) of the ceiling is discussed: the material of the beam itself in this case is airtight. In this case it is important to find an airtight connection between the insulation panels and the steel girders, on the on hand well executable for the artisans and on the other hand flexible enough to follow the movements of the steel beams. The elaborated solution must be carried out as follows:

- Preparation of the steel beams: the sides of the beams must be filled with polyurethane foam, pieces of XPS have to be adapted to the form of the profile and filled in laterally on the steel profile
- Now the panels of the internal insulation can be installed: here it is important that the penultimate strip of panels is the one directly positioned under the ceiling. Before, there must be installed a self-adhesive compression tape on the below side of the ceiling and around the beam ends, against which the topmost panel must be pressed
- Finally the remaining gap between insulation panels and beams must be closed by an adhesive tape (folded at a 90° degree angle).

Figure 74: Documentation of 2nd Workshop: Optimization of ceiling/wall connection (end of double-T-girder)

Solution for wooden beam ceilings:

In this case additionally to the airtight sealing between beam and insulation, possibly cracks in the wooden beam that pass through the airtight layer, have to be filled or closed. One possible solution here fore is the one proposed for the Weigh House: to close the fissures by drilling a well-defined hole in the crack and close it by gluing in a wooden dowel. The solutions for sealing wooden beams with different sealing compounds and adhesive tapes, tested within the project 3encult, are discussed. For the project Villa Castelli two of them, which showed also the best test results, would be suitable solutions. One is a “pasty functional coating”, consisting of structurally pure acrylic dispersion and is used in combination with a special fleece to be applied to the sealing point. This sealing is performed in three steps: (i) applying the paste-like material in the crack, on the beam and the surrounding area, (ii) pressing special fleece into the paste, (iii) applying second layer of paste-like material. The second one is a sealing system consisting of adhesive tape with adhesive primer and sealing compound. The crack must be filled with the sealing compound, using a cartridge pistol. After the material has hardened, the adhesive tape is applied around the beam on an adhesive primer.

On-site visit of case study solutions:

The workshop session ends with an on-site inspection with all participant at the 3encult case study, the Public Weigh House. The therefor developed technologies and solutions are introduced, in particular the appearance and the function of the high energy efficient heritage compatible window prototype, which has been installed on-site, is explained. Participants discussed if the concept of the smartwin historic window could be applied also in Villa Castelli.

Furthermore it is explained how the installation of internal insulation in connection with a wooden beam ceiling has been resolved here. The two solutions are explained: one with an “interrupted” insulation and the other possibility with the “continued” insulation (see also chapter 1.4), as well as the how to seal cracks in the wooden beam with wooden towels and how to connect insulation panels to the beams, in order to gain a continuous airtight layer also in the area of penetrating the wooden beams.

Workshop 11/12/13

Among: Energy planner (SOLARRAUM), scientific support (EURAC)

All relevant window/wall connections were discussed using first calculations in a two-dimensional heat-transfer modelling software. Based on the experiences made in the case study Weigh House, all joints were optimized with the aim to improve the heat losses and to assure required values of the surface temperatures in the critical points to avoid the risk of condensation.

Workshop 19 and 20/12/13: Definition of construction joints and of “post-evaluation” monitoring concept

Among: Architect (Carí), energy planner (SOLARRAUM), scientific support (EURAC)

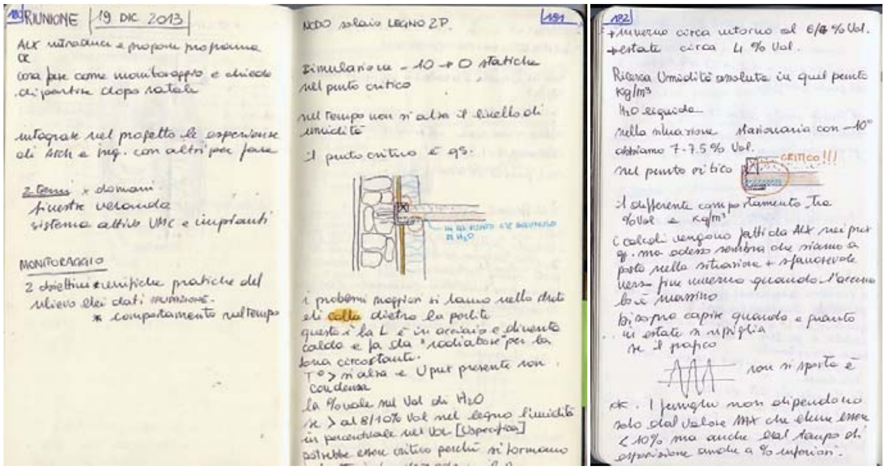
First section (19/12/13):

Several detail solutions were discussed, in particular the joint of the second floor ceiling with the exterior wall and the window/wall connection in the area of the veranda (columns in concrete).

Solution for construction detail (ceiling second floor): connection of laminated wooden ceiling to the exterior wall.

The wooden ceiling is beard on a continuous steel angle (L-profile) which has been pegged to the exterior stone wall. To diminish the thermal bridge at the steel angel, a 2 cm layer of cork was fixed on the backside of the profile, respectively 2 cm of XPS on the bottom and top side. Since the structure, because of the steel angle, is not diffusion open and at the same time the surface temperatures in the area on the backside of the interior insulation can decrease nearly to outdoor temperatures, there is the risk of condensation and accumulation of humidity at the point where the ceiling lies on the angle.

Static simulations (at outside temperature of -10°C and of 0°C; inside temperature 20°C) showed that the critical areas are the bearing of the ceiling on steel angle (underside of the ceiling) and the layer behind the interior insulation (glue), these two points are the areas with the highest accumulation of humidity.



180 RIUNIONE | 19 DIC 2013

ALX introduce e propone programma
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integrare nel progetto le esperienze di Arch e Ing. con altri per fare

2 temi x domani
finestre veranda
sistema attivo VMC e impianti

MONITORAGGIO
2 obiettivi scientifiche pratiche del rilievo dei dati [illegible].
* comportamento nel tempo

NODO solaio LEGNO 2P. 181

Simulazione -10 → 0 statiche
nel punto critico

nel tempo non si alza il livello di umidità

il punto critico è 95.

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la % reale nel Vol di H2O
se > al 8/10% Vol nel legno l'umidità
in percentuale nel Vol. [Uspecifica]
potrebbe essere critico perché si formano

182
+inverno circa intorno al 6/8 % Vol.
+estate circa 4 % Vol.

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H2O liquida
nella situazione stazionaria con -10°
abbiamo 7-7.5 % Vol.
nel punto critico

il differente comportamento tra %Vol e Kg/m³
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se il grafico
non si sporta è
ok. I funghi non dipendono solo dal valore Max che deve essere < 10% ma anche dal tempo di esposizione anche a % inferiori.

Figure 75: Documentation of 4th Workshop: Simulation of critical points at ceiling/wall connection

At the steel angel, it is interesting that not the area at the bend of the L-profile is the point with the highest humidity. The reason is, that because of the thermal bridge in the area of the ceiling bearing the temperatures of the profile in the area of the stone wall is still quite high, therefore is becomes like a “heater” for the surrounding zone, the temperature rises and the humidity does no condensate at this point.

Stationary simulations showed 7 – 7,5%Vol. of humidity in the critical point of the wooden ceiling. This is however below the critical range for mould grow, which is >10% over a certain period of time. While the dynamic simulation shows max. 6%Vol. in winter and min. 4%Vol. in summer.

The simulations confirmed therefor that there is no serious risk of mould grow in the area of the wooden ceiling, the detail connection can therefor executed as planned.

Solution for window/wall connection in the area of the concrete columns:

In the area of the veranda it is important for architectonical and conservation reasons to keep the proportions of the façade (rhythm and dimensions of columns and glazing area). It is therefore not possible to apply the same concept for the interior insulation also in the area of the veranda as proposed for the stone walls. This would change considerably the appearance of the columns. At the same time, the concrete has a low thermal resistance. To avoid a thermal bridge and the risk of condensation, it is therefore important to use a high performing material.

The solution developed within the workshop is to apply 2 cm thick vacuum panels to the inner side of the columns, while in the reveals between vacuum panel and the blind frame of the window a layer of XPS is installed.

Second section (20/12/13):

The aim of all partners involved in the project is to carry out a long-term monitoring both on building level in order to verify and optimize the energy performance of the whole building and on construction detail level to evaluate the thermo hygrometric behaviour of the single layers in the construction.

During the last workshop the monitoring layout was defined. The participants agreed that the “post-intervention” monitoring of the building will have the aim to (i) verify the real energy performance of the building, to (ii) document the quality of indoor climate, to (iii) validate the behavior of the material layers in the construction stratigraphy and to (iiii) control the risk of condensation in the material layers of critical construction joints.

The objective of the monitoring is therefore to optimize the performance of the building equipment and appliances in accordance to the user behavior as well as to avoid danger to the construction caused by any accumulation of moisture. In a second step the data acquisition allows to evaluate the refurbishment solutions in terms of their functional quality, the quality of their execution and their cost-benefit ratio or respectively their potential for energy savings.

To be able to integrate the sensors in the building envelope during the refurbishment work, all relevant construction details, the number and type of sensors and their position were defined.

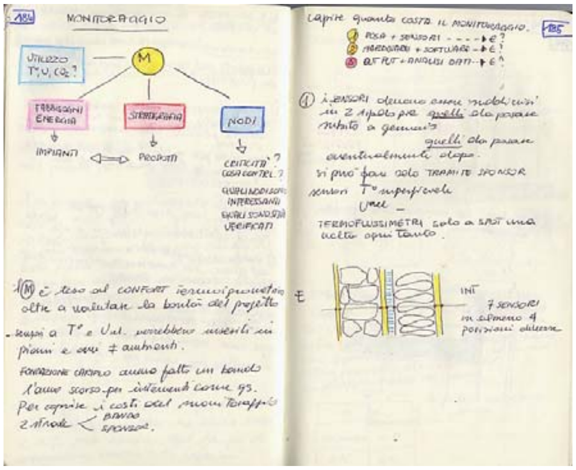

Figure 76: Documentation of 4th Workshop: Monitoring scheme and implementation of sensors into the construction stratigraphy

3.5 Conclusions

The results and the experiences gained from the project 3encult were supporting the implementation planning process of the building. Even if we consider the different construction materials of the building and its different climatic, architectonical and historical background, the methodology for developing and implementing refurbishment solutions is transferable and applicable. Especially when it comes to the development and implementation of “passive” solutions, the problems and solutions regarding the connection details from conservation, building physics and energetic point of view, are comparable. Furthermore, after the (i) analysis of the traditional (architectural) energy solutions in connection with climate and use of the building, the (ii) evaluation of its energy potential building and the (iii) heritage value of the single components, it is possible to start from a “solution set” of passive refurbishment solutions and adapt them within a multidisciplinary planning process to the individual demands of the building.

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