Methods and strategies for the sustainability of the historic built-up: studies and preliminary analyses on the “Monte” quarter in Piazza Armerina

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1. Introduction
This essay considers the relationship between conservation and sustainability with specific regard to the “Monte” quarter in Piazza Armerina. On the basis of the most recent literature, the first part discusses criteria and methods to address the issue of energy efficiency in existing buildings. The second part presents the results of the preliminary analyses and of the conclusions achieved after the implementation of energy efficiency improvement measures in some buildings of this historic quarter.

The study was carried out at two levels. A preliminary analysis was conducted at the block scale. It aimed at identifying the building units which had suffered invasive transformations or radical substitutions and, therefore, should be seen as “weak” areas¹. In this respect, these buildings may represent the objects of the most impacting operations. The second level concerned the evaluation of different available interventions at the building scale, with a view to the energy efficiency improvement in terms of consumption and heat loss abatement as well as of enhancement of the historic buildings' bioclimatic capacity. In order to carry out a preliminary evaluation of their compatibility, reversibility and retractability, we applied to our case study the suitable technical solutions and accomplished a comparison of the different “scenarios” of energy efficiency improvement.

2. The methodological approach
The search of a sustainable built-up is challenged by the huge amount of existing buildings. As far as the conservation culture and the building sustainable approach are concerned, recent qualified contributions prove the existence of common interests and objectives². Such a convergence is evident in the search of compatibility concerning materials and constructional solutions, in the attention to the interventions’ reversibility, in the preservation of the built heritage and in the implementation of minimal interventions³.

The preliminary consideration of the concept of sustainability and its development confirmed a great international interest as well as the absence of a thorough theoretical reflection, which urged an insight into the Italian and foreign best practices. In this respect, current literature and legislation demonstrate the need to address the issues involved by the relationship between sustainability and conservation both at theoretical and applicative level. These matters are briefly listed below and represent the core issues of a project for the historic heritage whenever new requirements raise a conflict between needs of conservation and transformation:

- considering historic buildings as “systems” of values rather than “assemblies” of components;
- referring the energy behaviour to the whole building, viewed as a system;
- identifying specific criteria for the energy efficiency improvement of historic buildings.

Only few qualified researches have deeply investigated the specific energy behaviour of historic buildings, suggesting methodologies of analysis and interpretation capable of combining the project choices with the material and constructional features of the built heritage. From a methodological point of view, the present study referred to two recent research lines developed at the Milan Polytechnic. The first one offered important theoretical reflections and highlighted the “systemic” value of historic buildings, bringing to light a careful interpretation of their energy behaviour, as opposed to the prevalent “performance” approaches. The second research line concerned the study of technical solutions for energy efficiency in important buildings. It ended up with a “commented vade-mecum”, which considers the relations between the different measures and the requirements deriving from the historic heritage in terms of preservation of its architectural, material and decorative features. Within this context, all these interventions are evaluated in relation to the factors of effectiveness, durability, cost and compatibility.

Following these perspectives, the present work required a preliminary definition of concepts and criteria which could strictly address the improvement choices according to the conservation needs. In this respect, the experience of contiguous disciplines provided some useful concepts. For example, the reflections on the reduction of seismic risks offered the concepts of “improvement” - already accepted by the specialised literature - and of “local” repairs, involving only limited portions of the building. These concepts allow setting the improvement projects concerning the historic built-up according to an overall enhancement of the performance, thus avoiding to apply the standards of new construction or - otherwise - incurring their complete derogation. In addition, similarly to what happens in the structural field, we deemed appropriate referring to a partition of the building in macro-elements characterized by autonomous and consistent responses. This helped to reach an effective model of energy behaviour. Finally, though not fully responsive to the maximization of energy performance, the “nominal life” concept helped to reflect on the possibility of moderate retrofits. According to this approach, it is correct to carry out only the strictly necessary improvements works which meet the needs to conserve the authenticity of the historic heritage. In this respect, the basic principle is that of minimal interventions, capable to combine quality, quantity and effectiveness of the actions. This means that further measures for a higher energy efficiency can be delayed to the future interventions, in order to benefit from the research progress and the development of more compatible and efficient technologies.

The case study was investigated with a multi-scale methodology characterized by a constant cross-reference to the building, micro-urban and urban scales. As far as the actions on individual elements in relation to the whole building are concerned, we adopted the systemic approach generally accredited by the most qualified studies. Within the preliminary analysis, we identified the parts with a major energy consumption, the ones which needed a more rigo-
rous conservation. Finally, we considered the weaker parts, to which the most impacting interventions could be applied. At the same time, the extension of such a comparative approach to the urban and micro-urban scales allowed to suitably relate the envisaged improvement to the preservation conditions, dimensions and position of the historic buildings. The establishment of energy sectors, encompassing architectural units with different preservative requirements, eased the choice of compatible and advantageous solutions, which were difficult to be implemented at the single building scale.

If a multi-scale approach is a distinctive element in any building process, it achieves a fundamental role and deeply connotes the strategies in the field of sustainability. Interventions at a building scale in historic centres like Piazza Armerina bare relevant impacts to the urban system and the landscape itself. In such a context, only a multi-scale approach enables a consistent evaluation of the choices and operational criteria, thus preventing unsuitable generalizations or a-priori restrictions. Therefore, sustainability must be linked to a complex set of balances generally existing in historic buildings and quarters, itself representing a resource to be protected.

3. The Monte district as a case study

The Monte district presents a central road (now “Via Monte”) crossed by a series of secondary narrow streets. This road system shapes long blocks formed by opposite rows of terraced houses. The block chosen as a case study constitutes the northern edge of the town. Despite the lack of maintenance and the significant transformations occurred, the block frontage looking at the “Costa S. Francesco” street and the valley below is of undoubted importance for the whole landscape.

The first phase of the study concerned the update of the surveys carried out at the end of the nineties, in the occasion of the preparation of the rehabilitation plan. After a little more than a decade, it was possible to evidence the signi-

Fig.1 - Longitudinal profiles of the examined block and a view of the Costa S. Francesco frontage
significant changes that affected several building units, as well as the increased state of abandonment. This phase was accompanied by the cataloguing of the block’s seventy units, evidencing their dimensions, conservation state, solar gain and lighting conditions and the most recent transformations. Moreover, it was possible to draw attention to the ground floor of the buildings, which are also characterized by a substantial height difference between the two fronts. The urban sections involving the buildings on the slope show the presence of basements with no air exchange. Such environments, originally used as stables or warehouses, reveal evident signs of moisture, which are accentuated by their exposure to the north. Their conservation state and finishing quality (which is generally quite minimal) urge for thorough improvements. On the other hand, their ancillary function made them suitable for use as areas for the buildings’ plants and installations. Our proposal identified this technical units at approximately every 50 m. Each plant would serve about 15 housings, according to a logic of mutual compensation and collaboration among the users. Involving the beneficiaries may indeed represent a path for the implementation of improvement plans at the micro-urban scale and for the spread of an active and strategic participation of the citizens. This would, in turn, promote the awareness of the heritage as a resource to be protected.

The preliminary study also included an in depth analysis of the traditional building techniques concerning the different types of horizontal structures, ceilings, roofs and windows. A specific concern was given to the facing masonry envelope, which is a widespread feature of the historic centre of Piazza Armerina. The survey operations allowed the cataloguing of eight masonry “families”. For each of them, we highlighted the different materials, the presence of regular rows, the elements’ dimensions and the mortar’s characteristics. The survey intended to systematically observe the salient aspects of the histo-
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Historic architecture, conceived as a set of consolidated elements of the building tradition of the urban context. This approach aimed at ensuring their conservation and enhancement, while adjusting the improvement strategies and safeguarding the aims of energy efficiency and sustainability. In this respect, despite the severe degradation and transformation of the block, it appeared that materials and geometries of the pitched roofs, gutters, downspouts and traditional timber frames were worth being protected with appropriate recommendations. Altogether, the detailed study of the building elements helped to provide a precise description of their composition and of their energy behaviour.

A specific investigation at the building scale involved the architectural unit recorded under number 22. Due to its characters, material and conditions, it constitutes a significant example of the building development and of the traditional techniques of this historic centre. In spite of its unitary appearance, the building consists of two separate and heterogeneous structures. The first one includes the first (at the ground level) and second floors. It reached its present configuration during the second half of the nineteenth century, as clearly denounced by the “1869” date carved on the keystone of the access arch. As mentioned before, it results from the aggregation of previous elementary units at the ground level and from the subsequent addition of a second

Fig.3 - Example of a building record (unit 22) containing dimensions and location of the parcel, surveys, photographs, information about constructional techniques and transformations
floor. The second structure covers part of the second floor and the third and fourth floors, and was implemented during the 1960s. The presence of these significant transformations suggested a consideration of suitable interventions related to the constructional features, the energy behaviour and the different conservative requirements of the two parts of the building.

The separate consideration of the building's macro-elements, with specific constructional, technological, material and geometric analyses, allowed the accurate evaluation of their energy model and the appropriate proportioning of the measures to the existing gaps and to the needs of material and formal safeguard. It was possible to detect the specific conservation state and the contribution to the building energy demand of each category of items (e.g. external walls, roofs, terracing roofs, window and door frames, ground level floors). In order to submit alternative technical solutions, we referred to the mentioned protocols elaborated by the staff of the Milan Polytechnic for the energy efficiency improvement of historically valuable buildings. We also verified and adjusted the envisaged solutions with specific reference to the material and constructional data of the case study, introducing some changes to the parameters of performance assessment. For example, we referred to the reversibility/retractability parameter, instead of that of durability, which is available only on the basis of the producers' assertions. The different combination of the various technical solutions and the subsequent comparison of the resulting scenarios led to the intervention proposal, on which we performed a precise audit and a global calculation extended to the entire building.

4. The simulation of energy behaviour
With regard to its annual energy consumption of 406.09 kWh/m², the audit placed the building in the G class. Another important factor is the annual CO2 emission, which is 81.22 kg CO2 m². The purpose of reducing the heat loss of each element of the architectural system could be achieved through a wide variety of solutions. Obviously, the possibility to analyze the energy behaviour of each sub-system does not necessarily imply its replacement. On the contrary, the partition in macro-elements, conceived as architectural parts characterized by an autonomous energy response, provides the opportunity to implement mutual compensations among the various parts of the building.

It must be recalled that the software for the analysis and simulation of the buildings' energy behaviour are almost exclusively designed for new buildings. Thus, it is quite problematic to use them in order to model the energy performance of existing buildings. Moreover, the difficulties increase in relation to old edifices, created with traditional techniques. The major inadequacy refers to the stage of the data entry, which becomes quite complex when we have an inconstant wall thickness or different interior heights or other anomalous conditions which are typical in the historic architecture.

The simulation for the sample building was carried out with the “Namirial Clima” software, version 2.1, but we had to take into account the mentioned problems and therefore apply specific corrective actions. The preliminary phase concerned the acquisition of the documentary and survey data. In this case, the problem was that the software libraries did not always encompass the
collected geometric and constructional information. For example, although possessing extensive constructional and petrographic data on the walls envelope, it was necessary to recover to an approximate description. As a matter of fact, the software archives did not provide a masonry model with the presence of brick fragments between the stones’ rows, which are quite common in the Piazza Armerina constructional typology.

On the other hand, since the software granted the possibility to enter a description of the individual components, the input of stratigraphic data was easier and less approximated in the case of wooden floors. The vaulted false-ceilings (made of reeds and plaster) were obviously not included in the archives of the software. For this reason, their elaboration was more complex. In this case, we decided to approximate their structure to that of a flat ceiling. Therefore, we assigned to this element the material and stratigraphic characteristics of the reeds and plaster vaults. Finally, as far as windows and door frames were concerned, it was necessary to adjust the double glass default data, which are quite obvious for a software conceived for new constructions. However, no adjustment possibility was offered with respect to the profile of the frames, which were obviously more efficient when compared with traditional wooden frames.

We carried out the final simulation through a comparison between three different improvement solutions designed for each macro-element. Thus, we considered the insertion of insulating membranes of conventional, innovative (energy efficient) and eco-friendly types. Finally, combining the different scenarios, we chose the definitive intervention proposal after considering which one was the most advantageous solution in relation to the need to preserve the authenticity of the historic building.

5. Results and conclusions

The overall evaluation of the energy consumption confirmed that most of the heat loss occurs undoubtedly through the exterior windows and doors frames, the ground-level floors and the envelope walls. On the contrary, even with the difficulty of gaining a model of its energy behaviour, we established that the vaulted false-ceiling structure made of vegetable fibre and gypsum mortar reduced the energy flow towards the superior cold environments. These conclusions emphasize the potential positive aspects of these elements, which deserve to be safeguarded and appropriately enhanced.

In addition, the energy audit confirmed the overall improvement of the energy performance even with simple retrofits such as the insertion of insulation layers, thus rendering useless the more widespread practice of complete replacement. Similarly, the study of the envelope masonry walls led us to recognize not only their historic and documentary value, but also their role in the overall balance of the urban scene. From this conclusion, we derived the clear choice to exclude any new plastering hypothesis, including any idea of external insulation, which would radically alter the consolidated aspect of the urban centre and would definitively sacrifice the authentic finishing. The solution envisaged in this first phase of the investigation was that of an internal eco-efficient insulation of a natural origin, encompassing appropriate measures to mitigate the
Fig. 4 - The heat loss before and after the intervention (1. Masonry envelope; 2. Ground-level floor; 3. Masonry boundary walls 1; 4. Leakages; 5. Internal walls; 6. Terraces; 7. Pitched roofs; 8. Masonry boundary walls 2; 9. 1st and 2nd floor envelope masonry; 10. Doors and windows; 11. Masonry boundary walls 3; 12. Ground floor envelope masonry; 13. Vaulted false-ceilings). The highest values of heat loss concern the elements not involved in the improvement action, such as the internal and boundary walls and the leakages which are automatically calculated by the software in relation to the amount of rooms and their location

thermal bridging. Such a solution bears the reduction of heat loss from 40 W/m² to approximately 6W/m².

In contrast, an intervention on the roofs - which are continuously affected by substantial deteriorations - is highly advantageous and significant in terms of energy efficiency improvement. In this respect, the bioclimatic potentialities of the pitched roofs and their need of conservation pressed for the maintenance of the preserved elements and for the insertion of an internal insulation. The repair and improvement of the false-ceilings may provide a further contribution to help the overall efficiency of the building.

We also verified that a significant contribution may be obtained from interventions on the frames. Indeed, their replacement with high-performance elements would produce a consumption abatement of about 65%. However, the insertion of low emissivity double glass systems would still reduce the consumption from 125.65 W/m² to 68.2 W/m². In fact, this kind of intervention is compatible with the dimension and geometry of the existing wooden frames, which are worthy of preservation. Another important contribution can be pursued with an intervention on the ground-level floors, made of dirt. The simulation considered the realization of a drainage, the insertion of insulating panels and the creation of a new pavement. All the proposed solutions permit important energy consumption reductions, with percentages ranging from 78 to 90% and good levels of reversibility.

These first synthetic results confirm the possibility of a substantial improvement of the energy efficiency, without forfeiting the needs and restrictions concerning historic buildings. At the same time, we can confirm the need to continue the search with an adjusted software and the help of a more accurate diagnostic. We programmed an additional phase of the ongoing investigation, consisting of a campaign of surveys in order to point out the thermo-physical properties of the walls and more accurately describe their energy behaviour. At the same time, the development of a prompt calculation procedure for the other units will allow a clearer definition of the urban scale scenarios.

The comparison of the data before and after the intervention shows significant
improvements. Although its results are not comparable with those of a new eco-efficient construction, it produces an energy consumption reduction and a CO2 emissions abatement of about 60%. Together with the enhancement of the intrinsic bio-climatic quality of traditional buildings, a further contribution to the energy efficiency improvement and to sustainability may come from the choice of the plant systems and a more effective involvement of the users in the waste reduction.

Notes
This paper is due to the joint effort of the authors. The paragraph 2 has been written by M.R. Vitale, the paragraph 3 by A.M. Savia, the paragraph 4 by F. Randisi.

2 Changeworks, 2008, Energy heritage. A guide to improving energy efficiency in traditional and historic homes, Changeworks Resources for Life Edinburg
7 Citazione Manurba.