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An Integrated Approach to Sustainable Building Design: The Case Study of The National Etruscan Museum "Pompeo Aria", Marzabotto, Italy

Angelo Mingozzi

Abstract

The National Etruscan Museum "Pompeo Aria" in Marzabotto Italy museum has been selected as case study of a set of EU Projects on the subject of sustainable architecture and energy efficiency and now it's a demonstration project of "MUSEUMS" EC FPV Project. The Project aims to define methods and procedures for an integrated approach to the sustainable design of new or retrofitted museums. Methodologies and best sustainable practices are applied in 8 demonstration projects located all around Europe.

Global retrofitting and extension of Marzabotto's museum are based on an integrate approach which foresees environment protection and rational use of resources as main targets. The project pays attention on balancing bio-climatic and passive solar techniques with active systems, in order to create adequate climate and environmental conditions for preventive conservation and, at the same time, to offer the best comfort for employees and visitors.

From an architectural point of view the project aims to re-organize the existing museum creating a visit path which includes an extension of the exhibition area by introducing new indoor and outdoor exhibition spaces (partially climate controlled), a total view point on the archaeological area and finally a multifunction room.

New exhibition space is located in a totally re-built building facing south.

The southern façade is protected, all over its length, by a wooden balcony which has specific solar control functions. Its performance has been extensively simulated both for thermal control (by means of dynamic simulation tools) and daylighting. Such balcony that works also as an exhaustive view-point for the visitors who wants to go upstairs and have a total perception of the area, is also connecting the multimedia room placed at the upper level of the building.

Indoor climate control is obtained balancing passive strategies with active systems, trying in any case to get most advantage of the building bioclimatic concept.

Results will be carefully evaluated through an environmental and energy monitoring programme and positive issues will define a set of possible actions to be replicated in museums with similar problems, owned by the Italian State.

The refurbishment project has been developed by the author in a professional context. Such experience has direct oucomes and it is complementary with research and didactic activities undertaken by the author in collaboration with the University of Bologna.

Keywords: Sustainable museum, integrated design, passive control of natural light and sol-air impact

1. Introduction

A museum represents nowadays a dynamic and evolving structure which modifies its image and appearance according to cultural and social transformations. Besides their traditional purpose – to preserve and to display human heritage – museums have today to comply with educational and recreational requirements.

Italy boasts more than three thousand small/medium size museums; these museums are mostly public properties and generally host exhibits coming from the site. They are often placed inside unsuitable buildings, which were not designed to house exhibitions; their indoor environmental quality and the energy performance as well are poor, thus many fixtures are needed to satisfy well-being of visitors and preservation of objects.

The National Etruscan Museum 'Pompeo Aria' in Marzabotto (Bologna) [1] has been placed, since its birth, inside inadequate structures: the fact is, some rooms that today house exhibits were originally utilized for rural activities, in the form of peasant dwellings and barns, even though the collection includes Etruscan finds dating from 3000 years ago.

It is evident how this museum urgently needed retrofitting and enlargement. The experience about these operations has represented an important chance to test and to show how sustainable architecture can apply to certain buildings, such as museums, having a very peculiar designation.

The retrofitting and enlargement of National Etruscan Museum 'Pompeo Aria' in Marzabotto, Italy, is one of the demonstration projects of 'MUSEUMS' EC FPV Project, which concerns retrofitting and construction of eight European museums in accordance with sustainability principles [2].

Design method and targets adopted in this case study have been investigated under the development of two other EC projects on energy savings [3].

2. Original Museum and Archaeological Site

Museum 'Pompeo Aria', located nearby an important Etruscan settlement dating from 6th century B.C., displays archaeological findings from that same area, which testify much precious information about everyday life of the Etruscan civilization [4] (Fig. 1).

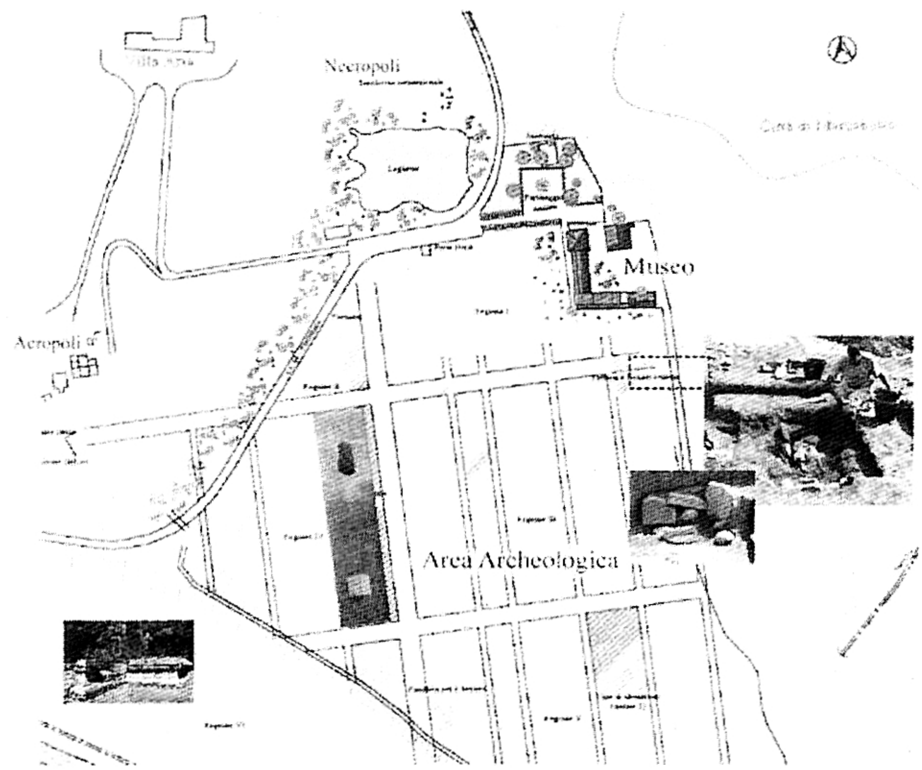

Fig. 1. Museum and archaeological park.

The pieces of art displayed in the museum come from the adjacent archaeological site. Exhibits are basically made of natural stone, marble, travertine, sandstone, amber, alabaster and terracotta. Metals exhibits are made of bronze, iron, lead, silver and gold. Museum also hosts some organic items (mainly bones).

Before renovation, the museum was composed by a two stories and square-based building made at the end of the 19th century that has at the ground floor the main entrance and an exhibition space and while the upper floor the keeper's flat. Close to this building a long and narrow one (extension of 1958) starts; it's oriented north-south with an arcade on its western façade used to exhibit some archaeological pieces. Southern we find another long building (extension of 1979) that at the beginning of the project hosted toilets, a boiler room and a little warehouse. During the renovation such building has been demolished and built up as new for exhibition purposes. Near to that building a small construction hosts a cafeteria, while some offices and new storages are located in an old rehabilitated barn by the area.

East of the new hall, a small construction houses a cafeteria, while a few meters north, offices and other storages are located in a separate building, formerly a barn.

The heating system was made of radiators and there wasn't any specific design for microclimate control: the system was not exactly carried out to satisfy exhibit conservation requirements. Much more, some radiators were located directly under the showcases, causing a great thermal stress to the exhibits. Lack of sun shading devices on skylight in exhibition spaces let in great amount of radiation in summer and raised the cooling load.

3. Project Targets And Design Concept

The retrofitting and enlargement Project has a general objective, which is to demonstrate that environmental control can base itself mainly on architectural solutions, with little necessity of additional equipments, even in exacting situations, such as the one herein described. Meeting sustainability principles together with architectural, visual, comfort and safety needs would prove that energy efficient techniques and technologies are definitely appropriate to public buildings, too.

Museums, and especially archaeological museums, have many requirements to be fulfilled; climate control inside museums is a challenging task, since not only people need to stay comfortable: internal environment must grant particular climatic conditions in order to preserve delicate exhibits; in every space devoted to exhibition, wrong indoor microclimate can affect objects and boost their deterioration.

With the help of a specialist in charge for conservation, it is essential to define suitable conditions under which pieces should be exhibited, in terms of light, temperature, humidity and so on; also it is crucial to clearly understand if exhibition requirements fit with users requirements, and how much variability can be accepted [5].

Accuracy in defining such targets has direct implications upon energy consumption and bioclimatic design implementation. When designing a museum accordingly to sustainability principles, the real challenge is to balance passive strategies with active systems, in order to assure the best indoor conditions for conservation and for comfort, and at the same time to increase rational use of energy.

Besides the architect and the conservator, many other experts are involved in the Project: mechanical engineer, museum director, exhibition designer, etc. Each one has his/her own experience and he/she has to be involved in the decision process. The architect, as the person that "controls the design process", needs some instruments to interface with other actors, particularly when dealing with conservation issues. Such complexity requires to define a design method: it would allow the cross disciplinary team to focus on shared priorities and to talk a common language, increasing chances that Project will succeed.

In order to organize human comfort requirements it is necessary to make an accurate analysis of all activities taking place in a museum. Once the activities and the relations between each other are known, it is possible to define the quality standards for people involved in each activity.

The exhibits conservation requirements can be defined with the same approach: firstly, the antiquities are divided into categories of objects with similar needs (this is a very difficult task because the damaging process depends on many factors). Once the categories are found, it is possible to define the range of parameters for conservation.

The parallelism between best microclimate values for comfort and for conservation makes possible a direct comparison.

The methodology ends with the definition of retrofitting/design priorities: now it is possible to proceed with different design scenarios.

Every phase of the Mazabotto's museum retrofitting and extension, starting from the site analysis, originates from the preset design method, which greatly helped to define general and specific targets; audit on outcomes systematically recurs during the whole design process.

Methodologies and technical solutions developed during the refurbishment of Museum 'Pompeo Aria' in Marzabotto have great potential to become a knowledge platform, and to be replicated in future interventions.

In detail, specific objectives regarding the Project are:

- to improve daylighting and to use high efficient lighting fixtures;
- to promote passive heating through the enhancement of solar gains during winter, as well as through the improvement of thermal mass and insulation;
- to promote passive cooling strategies by the following means: severe solar radiation control thanks to carefully designed sun shading devices; thermal mass increase; night ventilation and free cooling enhancement; ceiling fans;
- to install high efficiency active thermal devices as for instance a condensation boiler, ready to be easily integrated with solar panels;
- to set up a comprehensive control system using sensors to govern each active device (thermal units, artificial lights, ceiling fans for night ventilation), in order to satisfy actual indoor needs.

The architectural quality and functionality also play important roles: a precise goal is to create a sense of unity harmonising the three adjoining structures, which are the old square-based building, its extension toward south and the new exhibition hall.

A new important component, which contributes to achieve that unity, is a balcony (Fig. 2) that runs along the southern façade of the new hall, a light frame made of wood, quite independent from the walls, which perceptually and practically connects many different parts: at floor level it creates an arcade that continues the one beside the 1950s central building; it can become a space to show less fragile exhibits. At the two edges, elevator and stairs lead to upper level, where the balcony serves as walkway to a multifunction room in the south-west corner. The same walkway acts as well as a platform that provides a scenic viewpoint all over the archaeological site: visitors can look from above at the remains of the ancient village that guarded many Etruscan masterpieces.

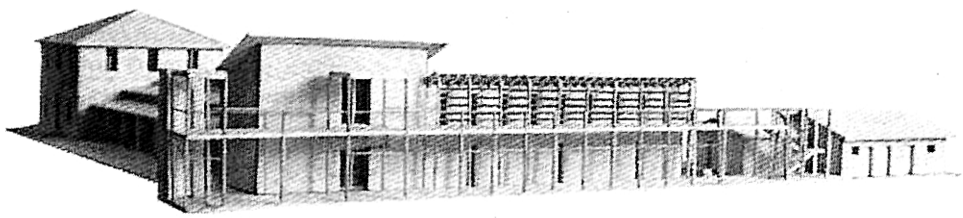

Fig. 2. Scale models including new exhibition hall.

4. The Balcony: An Integrated System for Solar Radiation Control

Screening devices integrated within the wooden frame provide solar control, aiming to regulate both thermal radiation and daylight. The external shading device calibrates interior daylight. Such device is combined with internal blinds in order to diffuse sun light coming from outside.

Inside the newly built exhibition space, a single big hall is split into two spaces with different functions by short partition walls: on the southern side a walkway has high illuminance levels because of openings towards the archaeological site and lighting redirecting systems hanged over the space. It conveys sense of connection with the outside, while the exhibition space, on the northern side, receives only softened natural light in order to keep a more stable environment and preserve frail archaeological finds.

During summertime, solar beam is screened and then diffused within the exhibition hall: a series of lamellae on the external side of the balcony reduces heavy solar radiation, while on the internal side more lamellae and other devices provide daylight diffusion.

Within the hall, in front of each window, heavy brick partitions shield direct radiation, in order to avoid glare as well as annoying reflections on showcases; the same walls provide thermal mass, too.

The system described above is designed to let in natural light through the lamellae during wintertime, in order to get some thermal gains; afterward the light is filtered and diffused (Fig. 3). The artificial lighting system integrates daylighting according to daylight amount and presence of visitors.

The balcony is designed to accommodate photovoltaic panels which could be installed in future.

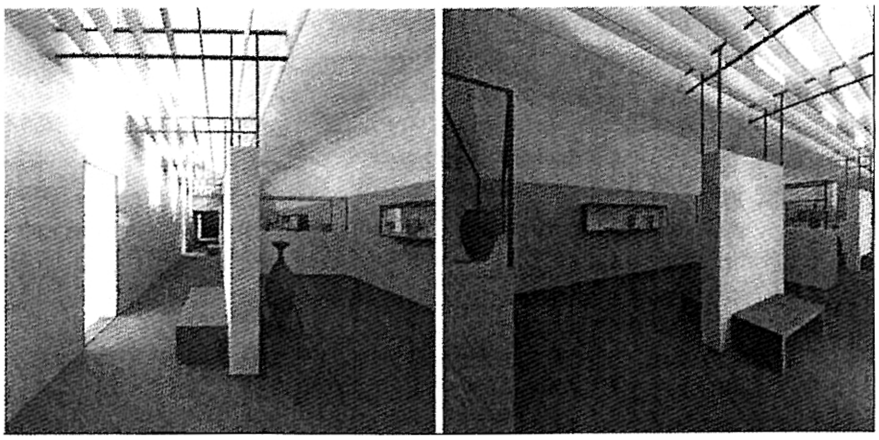

Fig. 3: daylight simulations (LBL Radiance).

5. Comprehensive Strategy to Balance Passive and Active Systems

Passive techniques are applied in this bio-climatic design both enhancing solar gains and reducing heat losses through the envelope during the winter time and controlling the sun radiation during summer time (Fig. 4).

In the new exhibition hall and the multifunction room, this process is obtained by a correct placement and sizing, but also a right orientation, of the glass surfaces together with fixed external shading, placed outside the openings and connected to the wooden balcony. This horizontal shielding controls the solar radiation in every season of the year according to indoor micro-climate and energy savings requirements. In order to avoid summer overheating, the roof tilt is faced to the north. The walls have a high thermal mass and insulation. The intaken air provides a good cross ventilation, and some openings in the counter roof improve the stack effect.

Air extractors equipped with fans are situated on the covering and through a specific control system they supply night ventilation during the summer, free cooling during intermediate seasons and air changes.

Solar radiation control, high thermal mass, ventilated roof and natural night ventilation aim to avoid any air conditioning system.

Heating system consists in radiant heaters placed under the floor: they use low temperature water, supplied by a high efficiency condensation boiler; a dedicated control system regulates functioning period and water temperature on the basis of external climate. Each climatic zone has a thermostat connected to electric valves (on-off) which control indoor temperature according to the set point.

During hot season the whole south façade is totally shaded, thanks to external screening devices such as roof protrusion and wooden balcony (designed to let the sun in during cold period); heat in excess is captured by solid walls during daytime and then released at night, directly to the outside as well as from the interior, via an integrated system of natural and artificial ventilation: good cross ventilation is provided by air intakes together with false ceiling openings; ventilation system is controlled both by CO2 sensors for air quality and indoor/outdoor temperature sensors. Sensor control together with an air changes timer control, allow free cooling when suitable and night ventilation during the summer. The thermal performances of the whole building were carefully investigated through dynamic simulation tools (Esp-R, Summer), and it was proved that during summer it is likely to achieve adequate indoor conditions without need of any active system: specifically, air-conditioning is unessential.

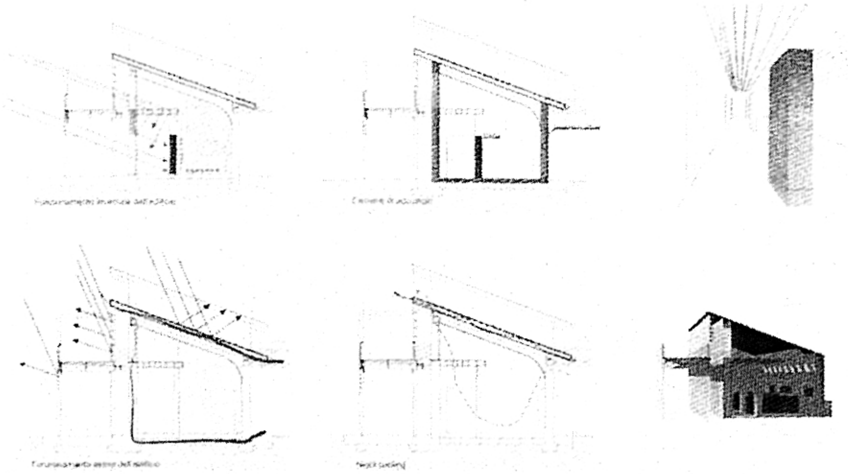

Fig. 4: comprehensive bioclimatic strategy, summer and winter control.

Indoor acoustic performance was accurately designed to guarantee people comfort even in crowded situations: optimal acoustic absorption properties of every material were inspected to get the better reverberation time; the result is that many different visiting groups can hear their own guide at the same time in the same space, without being disturbed by others.

Technologies and materials were chosen considering their effects upon health and environment: the Project stressed to minimize both emissions of indoor noxious substances and environmental impact associated with manufacturing and transportation of materials prior to construction activities; for example, locally produced and recyclable materials were preferred in order to reduce energy spent for transportation and polluting emissions.

Basic materials are: porous clay blocks, insulation panels made of wooden fibres, natural lime plaster, non-treated timber from local controlled cultivations (Fig. 5).

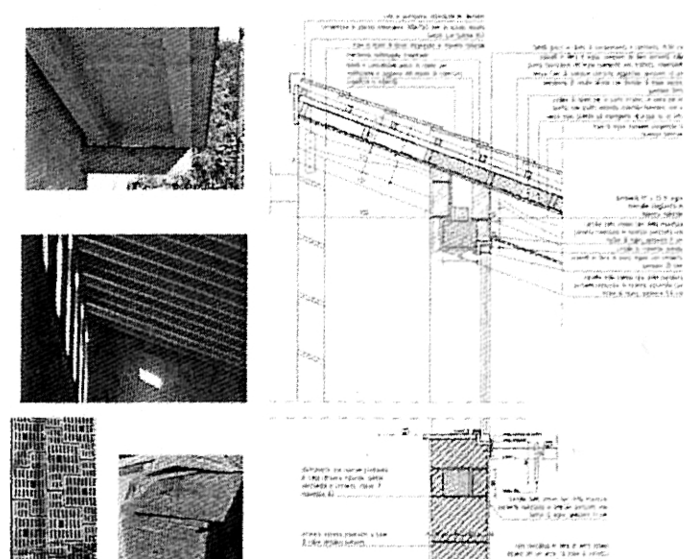

Fig. 5. Technologies and materials.

6. Conclusions

Even if the museum is very small, the comprehensive sustainable approach followed for its retrofitting and enlargement has made this case very significant. Many initiatives to disseminate results [6] [7] and promote visits have been developed. As an instance, during the construction phase a workshop was organized on field: it was open to students, professionals and builders, and some producers of sustainable materials gave their demonstrations and presentations: this was very useful in enhancing knowledge about the materials employed, especially in training museum builders on how to make use of them.

Expected energy savings amount to 35-40% (Fig. 6 and 7); this is mostly due to the comprehensive strategy for summer climate control, which allows not to install any active cooling system. Overall CO_2 emission should be reduced by 50%. The hypothesis verified through simulations during design phase will soon be tested on the actual case, monitoring main indicators of environmental and energy performance.

Museum 'Pompeo Aria' is still under construction [8]: incomplete parts (the timber balcony and some indoor finishings) should be concluded before the end of 2005. According to MUSEUMS Project purposes, both the overall strategy and the specific solutions have to be easily reproducible in other circumstances.

Fig. 6. Aerial view of the museum, with the new exhibition hall under construction.

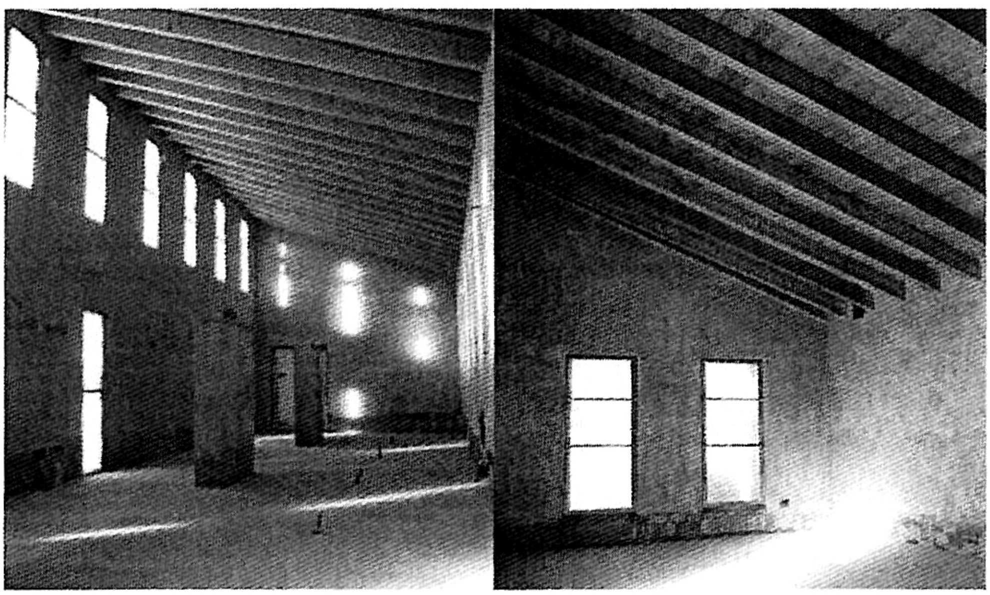

Fig. 7. Internal view of new exhibition hall and multifunction room.

Refernces and Notes

[1] Museum is owned by: Ministero dei Beni Culturali ed Ambientali Soprintendenza per i Beni Archeologici dell'Emilia-Romagna, Bologna (Head: Dott. Luigi Malnati; Museum's director: Dott.ssa Paola Desantis).

[2] The Project "MUSEUMS – Energy and Sustainability in Retrofitted and New Museum Buildings" (duration 2000-2004, contract n. Nne5/1999/20), coordinated by Alexandros Tombazis (Athens), aims to define methods and procedures for an integrated approach to the sustainable design of new or retrofitted museums. Methodologies and best sustainable practices are applied in 8 demonstration projects located all around Europe.

Angelo Mingozzi is the scientific responsible of the cross disciplinary design team of the demonstration project of Marzabotto and leader of the "Horizontal activity" about "indoor climate".

[www http://www.sustainable-european-museums.net/]

Design team and project coordination is made by: Ricerca & Progetto - Galassi, Mingozzi e associati, Bologna (Italy).

General coordination and scientific responsible: Angelo Mingozzi

Architectural design: Angelo Mingozzi, Marco Bughi

Structural design: Raffaele Galassi

Environmental control: Angelo Mingozzi, Sergio Bottiglioni

Electrical plant, HVAC: Giorgio Raffellini, Gabriele Raffellini (RAFF s.a.s., Bologna).

One of the results is the handbook: MUSEUMS, Energy Efficiency and Sustainability in Retrofitted and New Museum Buildings, European Commission Directorate, 2004; which includes the contribution of A. Mingozzi (chapter 3.4 – MUSEUMS case studies) and S. Bottiglioni (chapter 2.8 – Energy efficient museum design).

[3] "Retrofitting of Museums for Antiquities in the Mediterranean Countries" - JOULE III Project (JOR3-CT95-0013) and "Guidelines for the design and Retrofitting of Energy Efficient Museums for Antiquities in the Mediterranean Countries"- SAVE II Project (XVII/4.1031/Z/97-086).

This has been the occasion to orient design choices starting from an accurate analysis of the existing environmental and energy performances, carried out through surveys, summer and winter monitoring, visitors questionnaires, etc....

Design retrofitting hypothesis were verified with simulation tools to compare different strategies and perform cost benefit analysis.

[4] G. Sassatelli, La città etrusca di Marzabotto, Grafis edizioni, Bologna, 1989.

[5] The theme has been the object of a research activity - carried out by the authors - about indoor climate control inside historical buildings used as museums. Such activity, carried out since the 90's, both at ricerca & Progetto and at the University of Bologna, include the following projects: "Progetto Strategico C.N.R. per il Recupero Edilizio" (1989-1993); "Progetto finalizzato C.N.R., Tecnologie, Beni Culturali e Ambientali - Caso di studio la Galleria degli Uffizi a Firenze" (1998-99); "Operative and methodological instruments for the restructuring of the system of museums and libraries of St. Petersburg's University", EU - INTAS (1995-1998).

[6] A. Mingozzi, Un progetto di ricerca europeo sui musei ecosostenibili, in AA.VV., Costruire sostenibile l'Europa, (a cura di C. Monti, R. Roda), A-Linea, Bologna, 220-225, (2002).

[7] A. Mingozzi and S. Bottiglioni, National Etruscan museum 'Pompeo Aria', Marzabotto, Italy: an example of an integrated approach to sustainable museums design, Proceedings of PLEA 2004 - 21st International Conference Passive and low energy architecture, Eindhoven, 19-22 September, 2004.

[8] The construction of the new exhibition space has been co-funded by the Bank Foundation: "Fondazione della Cassa di Risparmio in Bologna".