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Building Low Energy Cooling and Advanced Ventilation Technologies in the 21st Century

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Bioclimatic architecture: the case study of the sustainable residential settlement in Pieve di Cento

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ABSTRACT

Energy savings inside buildings require a comprehensive design approach to balance bioclimatic strategies with the use of active systems.
A climatic responsive building aims to mediate external agents both to reduce climate loads and to create a healthy and comfortable indoor environment.
The sensitive approach to comfort gives nowadays more chances to implement passive strategies and especially the use of natural ventilation.
The residential settlement in Pieve di Cento is made with a general Masterplan designed according to sustainable principles. Different building typologies have been planned all following the same general rules. According to the new energy regulations following the European Energy Performance Directive, building energy performance requirements has increased along the years. The project described in the article aims to reduce energy consumption both for heating and cooling. Bioclimatic strategies and passive control techniques are applied both to the external spaces and the building. They include: strict solar radiation control, heavy thermal mass and insulation, building orientation, indoor space arrangement according to the orientation and night natural ventilation. The construction is made of bearing brick walls and wooden ventilated roofs and materials are selected according to LCA. Solar panels are used to heat domestic water. Heating system is made by a low temperature radiant heating floor combined with a high efficient condensation boiler. Floor radiant panels can be also used for cooling even if this is not a real necessity, thanks to bioclimatic strategies.
During each design phase expected performances have been continuously verified by means of simulations including dynamic thermal simulations tools.
The project - which is financed only by a private investor - represents a good example of smart use of simple strategies to reach energy efficiency targets both in the hot and cold season. The project was a good success on the market and demonstrates to be sustainable also from an economic point of view. The lesson to be learned is that the common battle to reduce CO2 emissions can be fought not only with extraordinary solutions, but a lot of goals can be achieved with a logical design which uses appropriately what we already have.

1. THE SETTLEMENT

The experience described here represents a successful attempt to implement sustainability in the current building practice, and it proves that energy efficiency and other ecological issues are not a prerogative of few exceptional cases.
The project (Fig. 1) concerns a land surface of 71,000 m^2 in the outskirts of Pieve di Cento, a small village near Bologna in northern Italy. Here, 11.900 m^2 of living surfaces have been built up in different building typologies since 1999. Las last buildings are now under construction. Although this has been a common private building initiative, which did not enjoy any special public incentives, it voluntarily followed the guidelines of the regional building code for sustainable architecture, since designers and the building contractor envisaged the strive towards sustanability as an opportunity to qualify the project and to pick it out from the other numerous real-estate offers, at little additional expense.
The very first step, before any planning activities, was Site Analysis: with the analytic investigation of local environment and climatic factors, it was essential to acquire information about specific opportunities and weak points, and subsequently define general targets. The climate is typical of the Padan plain: hot and humid summer season, and cold humid winters.
The customary routine, that everywhere produces anonymous neighbourhood, would have split the project area into many separated parcels, disconnetted and undifferentiated; but this risk was avoided in this case, since the building area was dealt with as a whole: the public green was choosen to work as general connective element, spreading from west to east, joining the new settlement both with the historical village and with the countryside. The green is intended to play many roles all around: it has specific climate control functions, it is a complement to pedestrian and bicycle pathways, a public place for recreation and for sports, a private space to relax and to cultivate kitchen gardens. Vegetation acts to balance microclimate through compact vegetation in

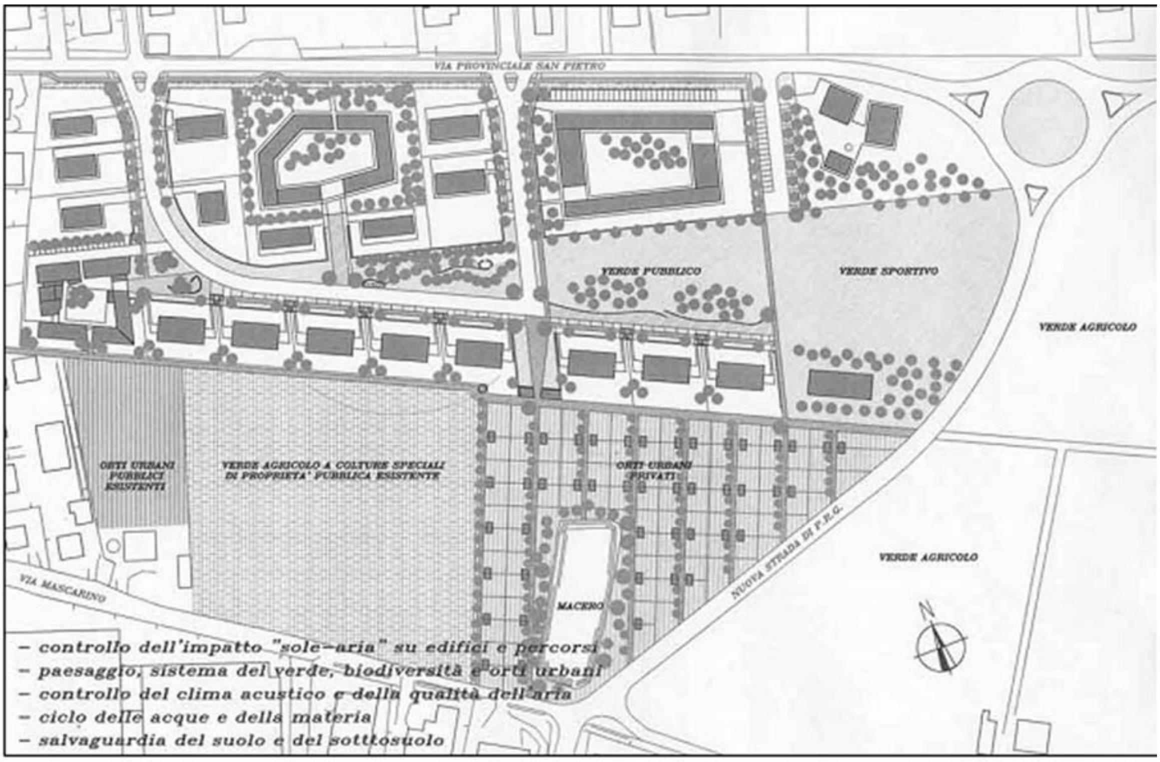

Figure 1: Masterplan.

the central public green spaces and it is arranged with consciousness in order to positively interact with buildings, to cast useful shadows and to screen cold winds. An old rettery basin, vestige of the old traditional country culture, will now work as expansion tank to regulate the regime of rainwaters.

2. THE BUILDINGS

Houses are thought as open bodies that freely interact with the climate, deriving the maximum benefit and sheltering for negative factors, in accordance with bioclimatic principles: the sun-air impact influenced main building features, such as orientation and shape (Fig. 2). Rooms are arranged consequently, and internal distribution follows a three zones skeme: the main spaces (living room, kitchen, and bedrooms) face south, in the middle are horizontal and vertical connecting passages, while accessory spaces, as garages and storerooms, look towards north (Figs. 3, 4). This layout is excellent to maximize energy performances and well-being conditions. Besides this kind of climatic control, the houses also turn their back on traffic, noise and air pollution, since main road lie north of buildings.
Many other solutions have been implemented to exploit the sun-air impact: transparent surfaces were designed together with overhangs, balconies and roof projections, using 3D models and solar views, in order to grant full shielding from summer sunrays and at the same time to maximize free heat gains during heating season. The general layout is characterized by single-pitched ventilated roofs that are tilted towards north so the northern wall area is minimized and the southern facade enlarged: for the same reason the difference in size affects windows, too. Still, windows are designed in respect with natural light optimization: daylight is a fundamental requisite for psycho-physical healthness, and its relevance required specific simulations (i.e. the average daylight factor was verified to be more than 2% in main spaces). A continuous checking of design objectives was done during the design process by means of different simulation tools. This has produced many modifications in order to evaluate sustainable targets satisfaction. Different options were took into account to check their effects on the solar control and on the other bioclimatic issues. This approach of continuous feedback and audit, which keeps alive the dialogue among all the involved professionals during the entire design period, is sure challenging but it is essential to eventually come to high quality results.

Figure 2: Two renderings (above) compared with photos of the last building during construction (below).

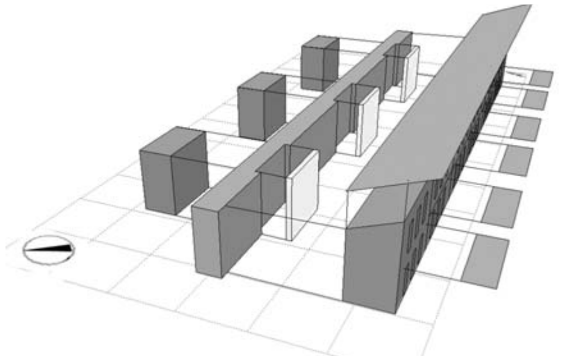

Figure 3: Exploded view of a linear house, where the typical three zones skeme is put in evidence: to the south (left) living spaces and solar control, horizontal and vertical distribution spaces in the middle, secondary spaces as bathrooms to the north (right).

3. TECHNOLOGIES AND TECHNIQUES

To maximize energy savings, passive systems are widely implemented: this way the need of active systems has been reduced, and so the costs of the buildings. For instance, bioclimatic strategies such as solar control, use of thermal mass and night ventilation, have made quite superfluous the use of air conditioners: this result, which was expected by dynamic thermal simulations, has been lately confirmed by residents.

Besides the wise management of sun-air impact, the building shell, coupled with suitable plant system, produces an effective hygrothermal reaction to climatic variations during the whole year and generate substantial benefits on well-being conditions and energy efficiency. Even though today Italian building energy regulations are cantered quite only on thermal resistances of opaque and transparent surfaces, this would not be a sufficient way to achieve good performances during summer. The best method, which is also recognizable in the local building traditions, has been identified in using bearing brick structure, which provides both thermal insulation and inertia and good vapour permeability. Walls are different according to orientation: a massive wall characterized by diffused insulation looks towards south, to exploit and regulate the solar irradiation; instead the northern walls construction packages include pure insulating layers, too, because priority is to reduce heat losses. Preference was in parallel given to environmental friendly materials, evaluated through LCA, and as usual for the entire project, the best solution was seeked through previsional analysis, in this case dynamic and multi-zone thermal simulation tools. They demonstrates that mass in walls and floors provide a more stable climate and consistently reduces energy needs in winter but most of all in summer, especially when in conjunction with other passive cooling techniques such as night ventilation, which cool down the stored heat when external temperatures are favourable (Fig. 5). The dwelling distribu-

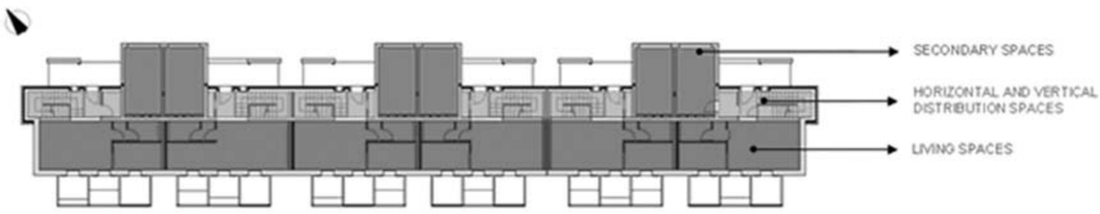

Figure 4: Ground floor: distribution and use of spaces.

tion is thought to allow an easy cross ventilation, which is much more effective than single-sided ventilation. Roof constructions have very low thermal transmittance and they are ventilated, to avoid at the same time winter heat losses and summer overheating.
Windows have low thermal transmittance, too, and they are certified for the highest class of airtightness.
The high inertia of building shell fits best with the choosen heating system, made of low temperature radiant floor and high efficiency condensing boiler fueled by natural gas; moreover, thanks to communication efforts made by designers, residents of many dwellings choose to pay a little more to integrate the heating plant with solar panels for domestic heat water, which were given as optional: in fact every house was designed from scratch with spaces, pipes and cables ready for the future easiest implementation of renewable energy sources.

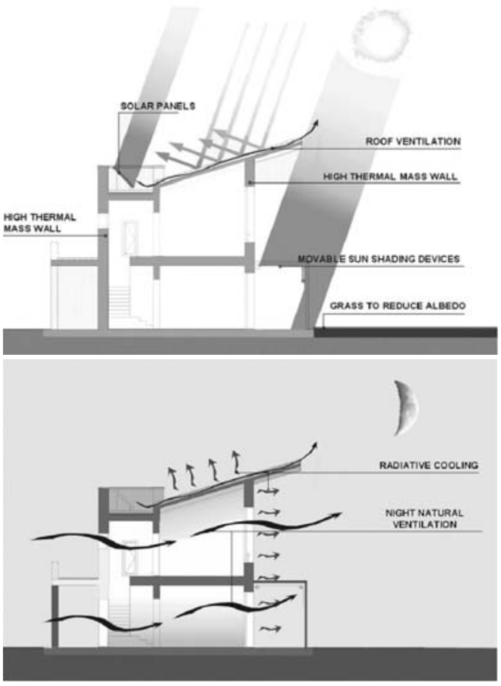

Figure 5: Sun air impact summer control. Solar radiation protection, heat storage, roof ventilation during the day; radiative cooling and natural ventilation to cool down thermal mass at night.

One dwelling was choosen as an excellence model, to represent the best achievable results in energy efficiency with reasonable expenses: it will implement an innovative controlled mechanical ventilation system. While requiring little energy to work, this CMV includes a heat exchanger (cross flow type with an heat recovery efficiency close to 95%) that greatly helps in saving heating energy during winter and in keeping good comfort conditions during summer by increasing night ventilation.
As for acoustics, specific care has been paid to construction packages and details of both external walls and internal partitions, to decrease airborne and structure-borne noise, especially between different houses, and between bedrooms and living rooms.
Water distribution systems are equipped with flow reduction devices and double flush toilets.
Electric systems are originally designed to minimize electromagnetics fields, through correct appliances and network pattern.

4. CONCLUSIONS

The project of Pieve di Cento represents a balanced compromise between the impulse toward sustainability on the one hand, and the ties due to the market and regulations on the other hand.
It is the highest reachable level of quality which was possible to get for that particular place and time, and in the authors' opinion (supported by the response of the market) it represents a very successful experience where the principles of sustainable building have been applied on a common private initiative. Thus this proves that the battle to reduce pollution and to save natural resources can be fought not only dealing with extraordinary solutions: the biggest chance to win that challenge lies with the capacity to apply simple but rational solutions in everyday practices.

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Figure: 8: Pictures of two buildings (left: tri-family typology, right: court typology) and below: some images extracted from the many computer aided simulations that were made to investigate buildings performances. The Project of Pieve di Cento is designed by the cross disciplinary design team of Ricerca & Progetto – Galassi Mingozzi e associati in Bologna under the general coordination of Angelo Mingozzi.