Semi-underground house models as new concepts for urban sustainable environment

Filiberto Lembo\textsuperscript{a}\textsuperscript{*}, Francesco Paolo R. Marino\textsuperscript{a}, Catiana Calcagno\textsuperscript{a}

\textsuperscript{a}University of Basilicata, Viale dell’Ateneo Lucano 10, Potenza 85100, Italy

Abstract

The underground and semi-underground construction is a building type whose traces are lost in the past: from Cappadocia to Jordan, man has left us countless testimonials of dug cities that, today, respond more adequately to the climatic problems. It is surprising to see how a building type, which has its roots in the remote past is today able to satisfy the needs of energy saving and of architectural forms which are continuously evolving.

The peculiarity of this type is the capacity to relate to the ground morphology by inserting in a “non-violent way” but adapting to the pre-existent conformity. Therefore, in a local mountainous context like Basilicata, land in southern Italy, whose building tradition is the semi-underground construction, a project experience such as that proposed in this paper can be the cue for a revitalization of the urban contest.

© 2011 Published by Elsevier Ltd. Open access under CC BY-NC-ND license. Selection and/or peer-review under responsibility of APAAS

Keywords: Semi-underground passive solar houses, sustainability, zero energy buildings

1. Introduction

Within ever more wide-spread cultural approach which is aimed to re-debate terms of relationship of the man and his environment, and to re-formulate economics, agriculture, industry, service industry and executive activities in terms of sustainability, a change is needed for the re-invention of settlement typologies.

They can’t more be these of historical city, for new energetic and ecologic objectives. But at the same time, it is necessary to consider and reaffirm the values of the European city, “high density - low rise”, so much studied in the design experiments of the ’70s [1], and which today should be compatible with the
requirements of compactness and orientation which are specific requirements of passive solar houses.

They are not sufficient passive houses devices (hyper-insulation and heat recovering from exhaust air) to grant settlements “zero energy balance”; it is necessary to establish a virtuous relation interchange with surrounding environment (sun, wind, atmospheric dampness, rain, vegetation, soil).

Semi-underground typologies can carry out an effective response to these requirements, both in the carrying out of new buildings, and in the re-use (both in infilling and in rebuilding) of existing urban settlements. And more, they can be very useful in the refurbishment of existing building complexes.

2. Semi-underground houses philosophy and references

As Italo Calvino writes in his book "Le città invisibili" (i.e. “The invisible cities”), there are many cities: the cities of desire, the city of memories, the thin city up to the invisible cities that are the dream that was born from the heart of the uninhabitable city, made by the destruction of the natural environment and the fragility of large technological systems. Today, a response to this crisis could be the bioclimatic city that, in its complexity, is a summary of engineering aspects, of the local building traditions and of the architectural trend of the times in which we live. As the world is a unique and complex system but also very small and frail where most of the urban population lives an urban life [2] so a responsible planning of the town is needed to ensure the quality of life.

In preparing the project these three elements are reflected in the analysis and study of modern solar architecture, underground construction and non-standard architecture.

The first of these references points out that the concept of sustainability has evolved, it isn’t about the individual buildings but is about the entire portions of cities:"settlements with zero impact", shows us how the small district of BED ZED made in South London, Bo01 in Malmo, or Vauban in Freiburg to, see Fig.1. These realities testify how the sustainability is in the transport system, in the public parks, in the community facilities and especially in the way of living of the people who are involved in the daily management of the district. We could imagine, in the next fifty years, a city where travel without damaging the environment, where you will use low-emission vehicles controlled by a computer, people will have a biometric notebook and health will be monitored constantly [3].

Fig.1. View of BED ZED, London
The design concept also comes from a strong desire to bond with the land: Basilicata, a mountainous area characterized by a variety of settlements carved into the rock. Human reality as Matera, Pietrapertosa or Castelmezzano, see Fig.2, were inspiring because they show how man is always established in close conjunction with the surrounding area while respecting the nature and its morphology.

The last reference is “non-standard architecture”. This arises from the rejection of the norms and standards according to the computerized pre-industrialization [4]. This occurs by a strong connection with the math no longer seen as purely theoretical discipline but as a concrete expression of the natural world around us.

A world made up of very complex but seemingly inexplicable phenomena which have a single bond: they belong to the realm of the unknown, so it can’t be explained by deterministic laws but the trend is towards something new: the chaos, seen as a dimension ruled by not defined laws where the disorder is complex [5]. This shift from formalism to mathematics intuitionism led to a new architecture which is free from precise shapes and drifting in a swirl of curved shapes, folds and rings as the works of Zaha Hadid, whose development takes place in an unpredictable way or those of Peter Eisenman that blend into forms that are the natural evolution of the land on which they alight, see Fig.3.
3. The project experience

All these references have served to outline the project which is the synthesis of free-form shapes that fit naturally to the ground in accordance with the principles of bioclimatic architecture, obtaining a sculptural object [6].

The site chosen to accept this settlement is Contrada Botte, an area of new expansion in the north of the city of Potenza. This is a south-facing hillside mainly covered by natural and fallow vegetation: oak trees, and some elm, which thickens laterally delimiting a central space free from any visual obstacle, see Fig.4. The hilly terrain and its great southern exposition allow to use of different bioclimatic technologies: in fact the Mediterranean climate provide an adequate energy, self-sufficiency to the building project. Visiting the site at different hours of the day and with a three-dimensional model, were assessed areas of shadow and light in the months of December and August, identifying the central area as the most suitable to accommodate the complex of buildings.

The complex of several buildings and spaces, that make up the district, was regarded as a living organism composed of parts that, despite their diversity, work together for the good functioning of the whole and are also self-sufficient [7]. As the body of a person is composed of heart, head and feet, the district has designed buildings such as the heart of human life buttons, the square is like the head with eyes that wants to seize the Potenza’s lines and the scenes of the mountains and the parking is as the feet that unites the city. Finally, a mechanized route connects from the bottom up the different spaces like a spine. Winding down the serpentine paths of the various buildings, such as a vein network, ends in the square that is placed on top of the hill, see Fig.5a. There is no distinction between the classic parts of a building but they are one winding that runs without interruption whatsoever filling and creating new spaces. It’s a single surface that developed becoming the first front, roof and finally way playing the roughness location and movement of the land that is not never flat and smooth because the architecture as an integral part of the wider world [8].

The design is inspired in its guidelines by the operation of dynamic systems, typical of a chaotic
system, represented by the strange attractors and especially by “Hénon Attractor”, see Fig.5b. The latter represents the intersection of the orbits of celestial bodies with an imaginary plane and its curvilinear is so light that fit well to the land morphology defining the shape of the buildings which are arranged around a central hub at the top of the lot: a square.

As in the attractor the lines develop in the floor as in the building they identify the real and concrete paths that developed in space, then become roofs by defining the total volume. Because the space, as Bruno Zevi says, is dominated by the physicality in relation to the movement that is the ability to interact with it by empathy or not [9]. The movement is visible in the roof of the building, whose wave development reproduce the natural slope of the land, in the facade which is marked by vertical currents whose slope and distance reproduces the oscillatory motion of the pendulum, see Fig.6, and in the plant which is part of the land with indentations and protuberances that define internal spaces of socialization cut across by elliptical volumes.

Fig. 5. (a) Planimetric distribution of district; (b) Hénon Attractor

Fig. 6. Prospective view of projected building
From a bioclimatic view the district was designed as a settlement where it is possible to walk through the system of the roofs of buildings that work as green paths that wind around the amphitheater square on the top. From an architectural point of view the building is on three floors and is composed of ten apartments and two private offices on the ground floor. The undulating roof, that as you level up, the number of apartments reduced. In fact on the first floor we have four apartments, and on the last there are only three.

The main function is residential, addressed to a plurality of users may be small families, foreign workers, couples or singles. The residential function is presented according to different types of housing such as apartments, three and four, developed on one level living with a total of 35 inhabitants, see Fig.7.

The aim of the project is to create a building that develops the social contact between people identifying a number of areas where people can meet in summer and in winter in places of conversation and sharing. So the building is developed in an area that has a wave pattern between the recesses and not, as if we were one of the bends of a river. This bends have the role to break the monotony of continuous corridor and to create meeting places that promote interpersonal relationships. The wave motion is repeated, even in the wall separating the apartments from the corridor, where the indentations indicate the entrance to accommodation.

The movement of the entire body of the building is done, even in the "front window" that is angled to the outside and whose surface is marked by steel current ranging from the bottom up intertwined with the another.

Specifically in the bioclimatic planning of the building the sustainable systems used, which are result of climatic and morphological analysis of the site, are different; the first is the partial silting of the northern front of the building resulting in a semi-underground building. This decision brings a number of advantages:

- mitigation of seasonal and daily temperature fluctuations due to high thermal inertia of soil that maintains a temperature much higher or lower than the outside;
- reduction of overheating due to the lower surface area exposed to solar radiation;
- protection from cold winter winds because the building becomes a whole with the land;
- a better integration in the environment.

Some disadvantages such as poor ventilation have been solved by coupling two systems for passive cooling. The first, by indirect contact with the ground, takes place by means of pipes laid deep in the ground, which cools outdoor air before sending into the rooms; this is possible thanks to the properties of
the soil that maintains a constant temperature at a certain depth. The second is the Barra Costantini system [10] consisting of ventilation chimneys connected to the interior by ducts which travel through the air vents located at the top of the wall, pulled out the internal air that is more warm. The building gets a plant system and technology that works for both heating and cooling environments, see Fig.8.

Fig. 8. (a) summer heat for rooms with southern exposure; (b) summer heat for rooms with northern exposure

Other disadvantages such as low light or reduced amount of solar gains of the exposed areas to the north have been addressed by modeling the coverage, which was raised in part from getting bored, and a double glazing system that illuminates the common internal areas of division, see Fig.9.

The second step was to define the shape of the building, whose elongated along the west-east axis allows to enjoy a large surface area facing south to capture solar energy. Internally spaces are arranged from south-west to south-east based on their needs for light and sun; in fact the spaces located in the
northern area are called "buffer zone" [11].

The building's heating is achieved by a "passive system" that uses the energy that is immediately available in the environment, this consisting of a wall of storage for the absorption and distribution of heat, and a solar greenhouse leaning against running along the length of the south front of the building. A buffer space is obtained that acts as a filter in the smooth transition of thermal heat from outside to inside.

This system in temperate climates such as ours responds very well because all of the thermal radiation that strikes the greenhouse is transformed into heat distributed to environments behind by the wall of storage and by ventilation ducts.

Also a series of measures has improved the overall behavior of the greenhouse:

- inclination of 10 ° to the outside of the glass, which provides protection from summer sun but allows the low winter sun to penetrate;
- insertion of venetian blinds in the cavity of the glass to protect from excessive sunlight;
- an insulated aluminum roll down at night that prevents heat loss to the outside;
- opening of vents at the bottom and the top of the glass for adequate ventilation system.

The roof of the building was designed as a roof garden which, besides creating additional space for socializing, has a number of environmental benefits such as noise reduction, absorption of electrosmog or fixing fine powder and functional advantages as the mechanical protection of the underlying layers, the damping of peak temperatures of the sheaths and protection from cycles of freezing and thawing. In addition, the slope of the roof of the building means that as you level up the number of falls resulting in
Paint contact points of the outdoor terraces that look like compartments that cut cross the entire depth of the building and getting real share in its hanging gardens. The house opens to nature and nature becomes part of the house. Sky, soil and horizon act as floors, ceilings and walls, in a game of mixed spaces, to reveal hidden spaces without compromising the richness of its surroundings [12].

Finally, the bioclimatic planning ends with the insertion of a small-scale photovoltaic system integrated into the façade of the building. Part of the panels were placed at the window blind parts of the greenhouse and part in parapet of the roof with the new technology of amorphous silicon panels that allow an application on any surface.

4. Conclusions

All that said, has served to define the project which is the synthesis of free-form shapes that fit in the land in accordance with the principles of sustainability. The main objective is to fit naturally in the environment. Therefore, the buildings have been partially buried along the northern front using the slope of the site.

This design experience allows us to understand how to transform our cities into "green cities" with the resources we are given by architectural and engineering studies. And it wants to be a demonstration of how we can have energy solutions that make our environments more livable by participating in a cultural climate that crosses all over the world and wants to transform our cities.

From a bioclimatic point of view the district was designed as a settlement where it is possible to move on foot and take advantage of the system of the roofs of buildings that function as paths. As these "roof-gardens", growing in space, show the development of the land and define the physical nature of residential complexes. And a semi-underground building involves a series of climatic and environmental benefits.

Think of building as proposed and its realization is like chasing a dream that one tiny little spark of fire can be born a great power: the interest and enthusiasm for the new bioclimatic architecture to be applied to our city.

The sustainable city could be the answer to the problems of our city put into crisis by the less of social relationship and the loss of idea of “good architecture”; so we can have an economic and a social re-birth.

References

[1] Benevolo L, Le origini dell’urbanistica moderna, Biblioteca di Cultura moderna, 1st italian ed. 1965, 1st english ed. 1968; 8th ed;1984.
[2] Burdett R., Kanai M. La costruzione della città in un’era di trasformazione urbana globale.Città Architettura e società, La Biennale di Venezia, 10° Mostra Internazionale di Architettura (10 settembre-19 novembre 2006) 2006; 1, Verona, Marsilio Editore., pag. 3
[3] Foster N., “Conversazione di Norman Foster con Ellis Woodman”, Città Architettura e società, La Biennale di Venezia, 10° Mostra Internazionale di Architettura (10 settembre-19 novembre 2006),Vol. 1, Editore Verona, Marsilio, 2006, p. 383.
[4] Burry M., “Demain La Production Numérique et architecturale Notes sur le non standard”, Architecture non standard, Parigi Editions du Centre Pompidou, 2003, pag. 62
[5] Sala N, Cappellato G.Architetture della complessità. La geometria frattale tra arte, architettura e territorio, Serie di Architettura Francoangeli, Milano;2004.
[6] Somol R. 12 Reasons to Get Back Into Shape. Content. Ed. Rem Koolhaas and Brendan McGetrick. Köln: Taschen GmbH;2004. p. 86-87.
Contributions

Prof. Filiberto Lembo has coordinated and provided the research objectives.
Msc. Eng. Francesco Paolo R. Marino has provided methodological and operational tools and checked the results of research.
Msc. Eng. Catiana Calcagno has developed and designed the project.
The contribution of the authors in editing and writing the text of the paper, was equal.