Artificiality and Naturalness: Semi-underground Houses and Their Role in the Construction of a Sustainable Urban Landscape

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Abstract: The contemporary interest, on one hand for a renewed relationship between city and natural landscape, on the other for settlement typologies intrinsically efficient from an energy standpoint took back the attention on the design of the dug city, or rather, almost completely excavated. This is an emblematic model of the requirement that deals with the factors of its environment, like sun, wind, ground, shadow and flora, forcing some designers to migrate from usual design methodologies, indifferent to these design parameters, and they are careful only to the “laws of form”, in search of criteria and fine calculation tools to optimize the configuration and the structure of buildings, in order to ensure that they can be managed as “passively” as possible. What it means, with the minimum contribution of plants to ensure the best satisfaction of comfort and psychological needs of users: not only lighting, sunbathing, ventilation, thermal comfort in summer and winter, acoustic comfort, but also view characteristics, quality of lighting and sociological aspects. In general dialectic between artifice and nature, the theme of dug architecture today is faced not only as one of the most interesting and rich suggestions, but also as one of those, in which the reflection on objectives, methodologies and tools is longer necessary, to the identification of a new way of urban living and effective solutions against energy consumption.

Key words: Semi-underground typologies, earth-sheltered houses thermal insulation choices, design models for dug cities, sustainable city planning.

1. Introduction

The unpredictable and unimaginable events of the last few years, from the Covid-19 pandemic to the war in Ukraine, increasingly lead to re-discussing the terms of the relationship of man and his environment, and to reformulating new urban settlement paradigms, which are inherently energy efficient and sustainable.

Today, more than ever, the need is fully felt on the one hand to re-discuss the ways of living, on the other hand to pursue new energy and ecological objectives: it is understood when a change is necessary to reinvent settlement typologies that can no longer be those of historic cities.

Passive house devices (hyper-insulation and heat recovery from the inside air) are not enough to guarantee the goal of “zero energy balance”; it is necessary to establish a virtuous exchange relationship with the surrounding environment (sun, wind, atmospheric humidity, rain, vegetation, soil).

Semi-underground typologies can provide an effective response to these requirements, both in the construction 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. The Dug City into the Mediterranean Landscape

The survey and study of medieval settlements in Puglia and Basilicata [1], constitutive nucleus of famous historical centers such as the Sassi of Matera or that of Massafra [2], or almost unknown such as those of Ginosa and Laterza, or abandoned at the moment of maximum development, such as that of...
Casalrotto di Mottola [3], and therefore perfectly legible in their unaltered characteristics, now make it possible to have a vast repertoire of knowledge on the typological, morphological and constructive peculiarities of the elementary cells, as well as the constituent ensembles of the urban and extra-urban rock settlements of the rupestrian urban planning of the Italian territory, especially medieval, but not only. These are all elements, of the grammar and syntax, of this urban planning of the excavation, which constitute precious tiles, complementary to the sub divo ones, in the construction of the Italian Mediterranean landscape, in the relationship that they establish (even by digging), between private built space, private enclosed space (for animals and/or vegetable gardens), relationship space (vicinia (urban or rural or neighbourhood community) for distribution, cistern, granaries, road), production space (trappeti (crushers) and cellars, vegetable gardens and cultivated fields), symbolic nuclei of aggregation (churches, crypts, monasteries, cemeteries); all these elements are usually situated within a very specific physical boundary (a wall) that divides the pittagio (“portion” of an inhabited center, a town or a city) or casale (village) from the outside, and with the use of very specific arboreal essences and medicinal or vegetable plants.

The contemporary interest, on the one hand for a renewed relationship between the city and the natural landscape, on the other for settlement typologies intrinsically efficient from the energy point of view, has drawn attention to the project of the city excavated, or rather, almost completely excavated [4, 5].

This is an emblematic model of the need to deal with the factors of the environment: the sun, the wind, the morphology of the ground, the shadows brought by the hills and vegetation, which pushes some of the designers to migrate from design methods that are neutral to the characteristics of the place, in search of synthetic criteria and/or refined calculation tools, through which to optimize the configuration and structuring of the building organism. Also, to ensure the most possible “passive” way (i.e. with the least plant contribution), to guarantee, as far as possible, the satisfaction of the comfort needs and psychological needs of users: not only lighting, insolation, ventilation, summer and winter thermal comfort, acoustic comfort; but also, sight, lighting characteristics, sociological adequacy, and so on.

3. Underground Architecture in the Dialectic between Artifice and Nature

In the general dialectic between artifice and nature, the theme of semi-underground architecture is imposed today, therefore, not only as one of the most interesting and full of suggestions, but also as one of those in which reflection on objectives, methodologies and tools appears most necessary.

The construction of the landscape was born with agriculture: it has been correctly written that the greatest transformations of the environment have been and are deforestation and cultivation: terracing for the planting of rice, olive trees and vines. It is therefore not necessary that one is in the presence of a Roman garden, with its opus topiarium, or of an Italian or French garden, Renaissance or Baroque, to be induced to reflect on the fact that every operation of transformation of the environment, and even the “conservation of order” (the thinning of the undergrowth, the pruning of the trees) introduces artificiality, and modifies the relationship between naturalness and artificiality.

Patrick Blanc, the inventor of green walls, vertical gardens, not of climbing plants, but of plants of all kinds, denounces it, taking it to the extreme consequences, powered by a recirculating irrigation/nutrition system, which allows covering with luxuriant vegetation facades of considerable height, such as the Museum of Primitive Arts at the Quai de Bercy, in Paris, by Jean Nouvel.

If the landscape in which man settles becomes a built landscape, it is clear on the one hand that it is a gradual process, which knows infinitesimal variations
and declinations between the elements that contribute to its naturalness/ artificiality; and on the other hand, that the city tends to constitute in fact one of the terms of the process: born to satisfy the needs of an increasingly intense exchange of people and things, of services, which were once material and are now increasingly intangible, and tends to concentrate as a solution that precipitates around a catalyst. It is no coincidence that the population living in the city has now exceeded that living outside it, and that megalopolises continue to grow in number and size, as has been well illustrated since the 2006 Venice Biennale.

In general, building partially buried but not completely underground allows solving typical problems of fully buried buildings: both of psychological nature (human life is conceived in the open air and in the sunlight; only when and where the normal conditions of life are altered or there are no alternative solutions, we resort to hypogeal choices) and physiological (there are also various reasons of a physical and physiological nature, since our senses and our perceptive needs are closely linked to the emerged world), as well as technical and economic reasons because it is necessary to take into due consideration the plant equipment that is necessary. Partially buried interventions, or architectures that blend into the territory, half-buried houses, bermed earth-sheltered homes hidden from the outside world with the use of backfill or other techniques that naturalistic engineering has been developing in recent years; use or reuse of tunnels and underground spaces of partially uncovered buildings sinking underground, or the attempt to recompose with the buildings against the ground a wound produced previously to the ground (Fig. 1), reduces land occupation by restoring a lost balance between the construction and the site. If partially buried buildings are covered with land and natural greenery, in addition to energy benefits, potential interventions for the creation or recovery of landscapes are also obtained, which are very positive if developed in degraded or marginal areas of the territory.

The negative psychological elements of integral underground architectures almost completely disappear, as problems related to natural ventilation no longer exist or are mitigated: direct sunlight for southern exposures, visual contact with the outside world. And all the advantages that already existed in full burial solutions are derived, such as: quality of thermal insulation and sound insulation, geothermal cooling or heating, high energy savings, low impact on the territory (Fig. 2).
4. Semi-underground Solutions

The problems related to climate change and the unexpected war in the heart of Europe in recent months, require radical choices, first of all in the direction of energy saving and, given that most of the consumption occurs in cities, and concerns the construction (in addition to transport), it is in that sector that it is necessary to operate, developing intrinsically efficient settlement models from an energy point of view. Since the exchanges of thermal energy between the spaces enclosed by the building envelopes and the environment are a function of very specific factors, the “correct design rules” clearly indicate the solutions to be adopted:

- compact the volumes, decreasing the surfaces of the envelope with respect to the enclosed volume;
- decrease the temperature difference between the enclosed volume and the external environment, creating “buffer spaces” or arranging the settlement volumes against the ground or inside the ground. In fact, the ground, below a depth of 3.5 m, is at a constant summer/winter temperature (11-12 °C, with small deviations depending on the altitude, latitude and climate of the location in question), and therefore, compared to the outside air temperature, it is warmer in winter and cooler in summer;
- significantly improve the insulation qualities of the envelope, both for the opaque and glazed parts;
- (in winter) open large windows to the south, to take advantage of the free solar gains, isolating them from the outside at night;
- (in summer) shield from direct sunlight the roof and the east and west side of the envelope, with external protections, detached from the built volume;
- control the ventilation of the rooms, adjusting it according to the humidity present and (in winter) recovering the heat.

It is easy to understand how the recall of the “fundamentals” just made, outlined the identikit of a “rock” settlement of the 21st century: what in other times would have been defined as a low rise-high
density type, but with all the views to the south, and otherwise wedged underground, viable in all directions, four-dimensional like contemporary art and architecture. The result is conceptual reinterpretation of the landscapes of medieval rock cities [6], a re-appropriation of the elements of the garden (the vegetable garden, the medicinal and ornamental plants, the orchards, the trees of great urban design) no longer isolated from the different settlement typologies, but reconnected in a design (informal, material, casual or the opposite, users will decide), like and more than the lost gardens of the American metropolises. Because, perhaps, it is not utopian to think that our level of urban civilization (and of civilization/society tout court) is such as to allow us to take care—as a group of people—of a piece of our urban landscape, on the roof of a house of some of us.

But the intent today is also to study the progress of the analytical design criteria of semi-underground buildings of any destination, with a focus on their role in the development of the sustainability of urban settlements, focusing, in a holistic way, on: site quality (high-density low-rise project, plugging of existing urban settlements, reuse of existing buildings, accessibility of public transport, integration between urban functions, integration with urban context and landscape, ecological continuity); consumption of resources (energy quality, eco-compatibility of materials, water recovery); substantial reduction of environmental burdens (CO₂ emissions, waste water, impact on the surrounding environment, heat island); quality of the internal environment (ventilation, thermo-hygrometric comfort, visual comfort, acoustic comfort, electromagnetic pollution); quality of service (Building Automation and Control System, Building Technical Management, Home automation, common areas for leisure time, accessibility, bicycle support, waste disposal areas).

They have been under investigation in many case studies which make an example (see Figs. 3-8, taken

![Image](image_url)

Fig. 3 Example of semi-underground terraced house (“domus terraneae”).
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Fig. 4  Example of semi-underground terraced house urban settlement.

from the research carried out at the Construction Technology Laboratory, La.Te.C., of the School of Engineering of the University of Basilicata), with different functions (residential, single-family or multifamily, terraced or hillside, or shallow atrium-courtyard), non-residential (offices, recreational, commercial, parking), with different geometry (dimensions and scale of project, fenestration arrangement, ground surface relationship), in different site features and climatic conditions (prevailing summer or winter design), and with different project features, enforcing most up-to-date strategies, chiefly passive, for plants. A careful design of the building-land connection elements is essential in order to ensure adequate levels of health and comfort for the habitable environments but also to make the techniques that are the basis of the bioclimatic project effective.

Studies on different insulation solutions (insulation on the roof only, both on the roof and on the perimeter and in the foundation, with a thickness ranging from 8 to 20 cm), have shown that, in winter conditions, earth leakages, however, are the main passive element of the energy balance, and must be controlled through the interposition of an insulation which, due to the increasingly restrictive limits of transmittance imposed by the Italian legislation in force, which is of increasing thickness and which in the situation (latitude and altitude above sea level) of Potenza (Basilicata, Italy) is now at least 16 cm if in the presence of external walls of the envelope with high
Fig. 5 Two examples of semi-underground terraced house with gardens and green roofs above.
Fig. 6 Example of semi-underground duplex (“casa palaciata”).
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Fig. 7 Semi-underground hillside house.

Fig. 8 Multi-family bermed earth-sheltered homes.

thermal inertia (Fig. 9). And it is advisable to move the insulation as low as possible, so as to preserve a high inertia for the horizontal boundary of attachment to the ground, which is useful for the summer behaviour of the building.

Designing to defend against the heat means, on the other hand, for an underground building for 5/6, exploiting the thermal inertia of the ground to avoid overheating, and therefore increasing the contact surfaces with it, and not placing insulation.
Moreover, the analyses carried out with the aid of simulation software and the comparison of the isotherms in correspondence with the building each time being analyzed (in winter and summer conditions) showed how the insulation of the roof was arranged horizontally along the upper perimeter of the building is generally the best insulation strategy, at least in a Mediterranean climate, optimal for both summer and winter thermal conditioning of the half-buried houses (Fig. 10).

In addition, the appropriateness of a project to the climatic situation of the site in which it operates consists in the energy balance of these two opposing needs, also taking into account the specific conductivity characteristics of the soil, which depend on its geological quality and the amount of moisture present in it, as shown by the studies carried out many years ago by Kosciuszko Foundation [7] at the University of Colorado, and confirmed more recently [8].
5. Final Considerations and Conclusions

Caves, underground or semi-underground structures, rock structures, carved and mixed structures: these are “negative architectures” that live in a close relationship with the earth, with nature, for this reason they seem to express, more than others, a primordial need. In fact, underground architecture often implies religious and mystical meanings and inevitably refers to the idea of the cave and therefore to the strong and ancestral image of the refuge. While the cave is rooted in the site in which it stands and is already able in
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itself to meet the needs of man, its positive opposite is the hut, the product of reason and man’s control over nature [9].

Yet, despite these connotations being unavoidable, underground architecture is not necessarily identified with the concept of “archaic”, on the contrary it is increasingly an expression of modernity. In this sense we can mention what we can define as a sort of underground urbanism, a myriad of invisible paths that branch out, creating a real underground dimension of the city. The idea of an underground city, which is generally perceived as unhealthy, dark, humid, suffocating, funereal and does not enter into the common sense of living underground, in some cities with a particularly harsh climate, has been overturned, and is becoming the winter complement of the sub divo city (see e.g., Toronto), just as in the Middle Ages the rock settlements were the complement of the hill towns (Refs. [1, 2] already cited).

Rock civilization culture in architecture represents a powerful instrument to question the planning process [10, 11] as an intellectual exercise and to subvert common and consolidated structures and assumptions, by using methods at our disposal (historical method and/or scientific ones).

If we thoroughly change the point of reference regarding sub divo architecture, all that we consider banal and natural there, must be reconsidered, discussed and “re-planned”.

It is possible to define new paradigms for contemporary architecture, which appreciate diversity even more, especially when it derives from the rediscovery of a very rich historical heritage.

The building is born from its relationship with the ground, with the sun, the rain, the dominant winds, the light and the view. For every room, the relationship with the outside is not obvious: it must be conquered and therefore different opportunities for the use of the loft, shed, solar fireplaces, systems of day lighting, mirrors and others are possible when one considers the relationship with the landscape. The architecture considers the position of the sun and the amount of available light as we move through the seasons.

This results in a contemporary architecture that is developed locally but has the potential for universal application.

Contributions

Filiberto Lembo coordinated and provided the research objectives. Francesco Paolo R. Marino developed the various aspects of the research, the methodological and operational tools and verified the accuracy of the results achieved. The contribution of the authors in reviewing the manuscript, editing and writing the text of the paper was the same.

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