Underground Contemporary Houses in the North of Portugal

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Abstract

Using nature itself – on prehistoric caves – or as inspiration for their artificial constructions - such as in one of the first known settlements: Çatal Huyuk in Anatolia, man always looked for underground shelter.

The North of Portugal is characterized by a disperse territory occupancy, what is problematic due to infra-structures and transport environmental costs. This reality has diverse causes: accented topography, parcel split of soil due to multiple transmission of property, an intensive labour and delocalized small industry. The generalized access to individual transport in the last 30 years accentuated this phenomena, that is now irreversible, but economic paradigm is now changing drastically, with small industries closing and increasing unemployment, what is now impelling the return to individual means of subsistence, such as private poultry. But a lot of soil surface is now blocked for agriculture, due to the existence of small disperse buildings that pop up on territory, difficult accesses and limiting the insulation to potentially productive soils. This is especially critical on South oriented slopes. Increase density is now utopia for this region, so a strategy proposed for dealing with this reality can be to integrate new constructions on terrace slopes, leaving the housing upper and immediate vicinity soil more easily available for agriculture and reducing visual impact of buildings on landscape.

1.Introduction

Underground housing is usually associated with archaic, unhealthy, poor conditions. However, underground buildings have many qualities including low temperature oscillation, better acoustic performance and higher protection against intruders in comparison with conventional upper ground buildings. Global warming and violent social convulsions announce the forthcoming era where security and protection will become major concerns. In this paper different types of underground housing are presented and some contemporary examples in Portugal are analyzed.

The use of underground housing dates back to the first human settlements. Villages began to develop during the Neolithic age, in Minor Asia, such as Çatal Hüyük in Turkey (6.700-5.700b.C.). This settlement consisted of houses joined together so that the roofs formed a continuous surface from which the interior could be accessed by stairs. Doors also served as windows for lighting and ventilation. In addition, some small high openings appeared in walls (clerestory), a solution that is repeated in temples of the middle Babylonic era (about 1.500b.C.) such as the Kurigalzu Palace (Peraza Sánchez, 2000). The Sumerian houses (2.870 to 2.370b.C.) consisted of rectangular compartments, positioned around a courtyard, with a hole in the ceiling from which light and air penetrate. The only connection to the street was a door.

Nowadays, underground settlements are still characteristic of several regions in the world. The most abundant are located in China, in Hunan, Shanxi, Shaanxi and Guansu provinces with approximately ten million people living in underground houses. Dwelling caves are found mainly in northern Shaanxi Province, in Yan'an and Yulin. They are built in the Loess mountain slopes. Cappadocia in Turkey is also known by its underground constructions which are still being built nowadays using the same constructive system as in the past. Figure 1.1 shows an example of a recently built hotel in Göreme, Nevşehir province in Central Anatolia. Other important examples of traditional dwelling caves can be found in Iran, Tunisia and Spain.

2.Geographical characterisation of Portugal

Geographical physical characterisation is important to understand the possibility of using underground housing, especially regarding the climate and the soil properties. In terms of climate there are three regions: Atlantic Portugal (wet Iberia, at the Northwest), Portugal “transmontano” (dry Iberia, at the Northeast) and Mediterranean Portugal (arid Iberia, at the south of the Tagus) (Ribeiro et al., 1987). From the topographical point of view the Tagus River

Figure 1.1. Underground Hotel in Cappadocia

separates two regions: the northern (with predominance of high relief) and the southern (with a predominance of plains). Portugal is divided into three major geographic and cultural areas:

• Northwest region: presents small reliefs, opens over the Atlantic Ocean by the broad valleys of the rivers that flow towards northeast-southwest. There is an influence of the regulatory action of ocean winds which gives a temperate climate, with little temperature fluctuations, cool summers, abundant rainfall and cloudy skies;

• Northeast Region: has mountains and plateaus cut by deep valleys and embedded rivers. It's isolated by a coastal relief, from the longitudinal distribution of maritime influence. Presents the same characteristics of the Iberian plateau continental climate: high temperature lags, harsh snowy and windy winters, dry and hot summers.

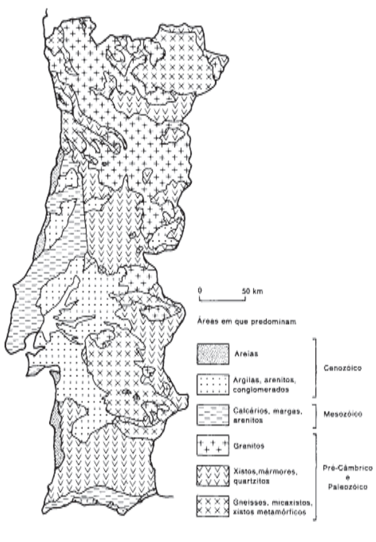

Figure 2.1. Lithological diversity in continental Portugal
(Brito 1994)

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• South Region: Mediterranean climate. It presents temperate winters, hot and dry summers, clean skies and little pluviosity. Although less contrasting with the interior, the south coastal region of the Tagus also provides the regulatory influence of the sea. Even though it is always Atlantic, in Algarve it serves as a vestibule of the Mediterranean (Ribeiro et al., 1987).

The lithological characteristics of the soil are also important to understand the feasibility of using underground construction and their more suitable types. Seven tenths of the Portuguese territory belongs to the "Hisperic" massive. It presents erosive and metamorphic rocks such as: granite, schist, marble and some quartzite outcrops (Brito, 1994). This massive contacts only with the Atlantic Ocean in the west coast, from Ovar to Sines and in Algarve, as it can be seen in Fig. 2.1. The rest of the territory present two distinct types: in the west and south predominates calcareous, margin and sandstones, but also clays and conglomerates; in the basins of the Tagus and Sado rivers predominate clays, sandstone and conglomerates.

3.Underground examples in Portugal vernacular architecture

This section seeks to describe the changing requirements of comfort in housing throughout times. The relation to the living modes, ranging from the shelter, to temporary housing and finally to permanent housing will be presented and discussed.

The relationship between housing and the immediately available resources only has an absolute value in the early stages of human habitat. Moreover, even at those levels, there are always plenty of scope for architectural changes, giving freedom to the conventions and local ideas to find their own expression (Keesing, 1961). The relationship between materials' availability on soil and primitive buildings is direct although, according to this author, leave some space for manoeuvre. What allows the presence and determines the types of underground construction are mainly the characteristics of the soil, as well as the culture and climate.

With industrial revolution the transport of people and goods generalized. Building materials started to result from industrial processes taken up in factories and then transported to store places and to site works. Because of this the link between the availability of materials in the soil and their use in construction changed, becoming significantly diluted. Economic issues are those that almost exclusively began to influence the types of materials used and thus also the constructive systems. Industries started to be located near raw materials extraction, more for economic than environmental reasons. This centralization of production increased the average distance of building products from the extraction to the work sites – with consequences on transport energy costs. Also the industrialization of construction materials, though more economical, is actually much more energy demanding and pollutant that the construction using intensive manpower and local materials. This happens in traditional underground constructions in Cappadocia / Turkey. Using only a digging hammer, one man can take between two weeks to eight weeks (depending on the hardness of the soil) to dig a compartment for a 20m2 dormitory. Based on a study from the author (Mendonça, 2005), it could be concluded that the economical cost for constructing a compartment of this size using a conventional constructive system (hollow brick / concrete) is approximately 500€/m2, not considering the cost of soil or windows. Following a survey that the author took on Cappadocia recently, considering only handwork, the cost is between 50 and 250€/m2, meaning that this type of construction is significantly more economical. The same comparison could be made about constructions in South of Spain (for example in Guadix), where the soil and the dryness of climate, allow the use of directly excavated spaces.

In recent years, the growing energy efficiency requirements led to a new approach, focusing less on the economic cost per se and more on environmental and material costs. Using local heavyweight materials, needed to increase thermal inertia and acoustic protection, begins to be considered in order to allow a compromise between pre and post occupancy environmental costs. As referred previously, intensive labour can be interesting not just for environmental reasons but also because it stimulates local economy. So, it is also a more sustainable approach from the social point of view.

Since the first buildings documented in the Portuguese territory, and until at least 50 years ago, the constructive systems used in housing buildings in Portugal were mostly mixed in terms of weight. These were characterized by heavyweight envelope structural walls, i.e. with approximately 1000Kg/m2 considering an average thickness of 0.40m of massive stone – like an evolution of natural caves. In areas where the stone was not available, adobe was used, what could be considered as an evolution of artificially dig constructions. The floors and roofs were lightweight, made of timber - about 50Kg/m2 the floor and 50 to 150kg/m2 the roof.

By the lack of efficient means of transport, materials used in the walls of traditional homes, were closely associated with the local availability of raw materials and manpower. Thus, the materials used for its construction correspond directly to the lithological characteristics of the soil, shown in Figure 2.1.

Apart from the materials, with particular emphasis on the characteristics of the envelope, the morphology of housing contributed significantly to the evolution of the thermal performance of houses.

All primitive buildings were no more than shelters in the current sense of the word. It should however be made a distinction between shelters and primitive buildings. According to Veiga de Oliveira et al. (1969), shelters are buildings with very limited occupancy, temporary or even occasional, in some cases mobile, with rudimentary forms and systems or styles with regional characteristics; the primitive buildings have permanent occupancy, well defined building systems with sharp typological or regional differentiation. Construction progressed to a traditional architecture, gradually from the sixteenth century until the mid-twentieth century, when the presence of a uniformity of typologies could be verified. Some typological differences between North and South and between coastal and inland, beyond the inevitable differences between urban and rural areas could be noticed.

The first shelters that man used to protect against the harsh climate and weather, present themselves in various forms, corresponding to different stages of evolution. Some examples remained in Portugal until today, or until the last century, including the following types:

• natural shelters - caves, grottoes and limpets;

•Semi-natural shelters - take part of rocks to build in these, as example in Figure 3.1;

• Artificial shelters - in stone, in stone and vegetable materials, entirely with vegetable materials.

Figure 3.1. Semi-natural shelters: Serra da Peneda (above) and Monsanto da Beira (down) (Veiga de Oliveira et al., 1969)

Figure 3.2. Artificial shelter with coverage: Leboção, Chaves (Veiga de Oliveira et al., 1969)

Figure 3.3. Primitive circular house of stone: Chafurdão in Ribeira da Amieira, Castelo de Vide (Veiga de Oliveira et al., 1969)

The artificial shelters in stone with roof also in stone, appear in some areas of the country, like “Trás-os-Montes”, “Beiras” and especially in mountainous areas. These are small buildings in overlapping stone, as shown in Figure 3.2, used as shelters for shepherds, farmers or camp guards. This type of construction is based on the dolmen, and eventually stones or parts of these constructions may have been used. In some cases the artificial shelters with stone take advantage of walls and terraces for at least one of the walls.

Figure3.4.Stone primitive square plan construction: two floors oven in Branda do Real, Serra da Peneda (Veiga de Oliveira et al., 1969)

Huts, with circular plan in stone walls and conical coverage made of vegetable materials still exist in some areas, particularly in Algarve mountains and in “Alentejo”. They are used now as barns, but there are still reports of some been inhabited till about 100 years (Veiga de Oliveira et al., 1969). These typologies evolved to rectangular plan, the origin of modern housing typologies, offering larger and better conditions of living.

The last group referred was built entirely of stone in circular or square plan with false dome. The coverage was made with rows of stones that get closer to the centre as they develop to the upper part, to form a false dome. The constructions of this type can be seen on Figures 3.3 and 3.4, with circular and rectangular plan, respectively.

"(...) These are very poor forms of housing, where people lived in large - sometimes total - discomfort, that could be hardly accepted today, and are therefore doomed to disappear, voted in the general contempt that they deserve, or integrated into contexts that have evolved beyond" (Veiga de Oliveira et al., 1969).

In mountainous areas of Northeast, homes were generally composed of two floors: ground-floor and first floor. They use the slope of the land and, in some cases, the rocky outcrops as wall or base. They have a direct entry to each floor, or an outside staircase made of stone, held to the front facade. Roofs are also frequent in stem, used in these areas for their good insulating capacity, as in the example of the house in Boticas presented in Figure 3.5.

In the ground floor house in Alentejo, the wall material is predominantly rammed earth. This allows greater thermal resistance of exterior walls combined with a good heat storage capacity, which is suited to the hot and dry climate. The external lime finishing allows a lower absorption of solar radiation. The construction is ground floor and usually with a minor form factor compared with the rest of the country independent house typologies. On villages in “Alentejo”, the houses present only one door in front and few windows of small dimensions. They are joined together in residential clusters.

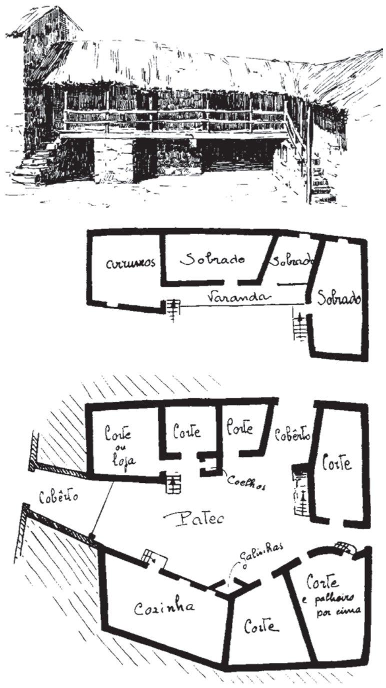

Figure 3.5. House in Boticas, Campos. Patio view and 1st floor and R / C plants (Veiga de Oliveira and Galhano, 2000).

In rural isolated farm houses of greater size, the “Montes”, bedrooms (Quarto – in portuguese) are often in the middle of construction, as shown in Figure 3.6, with no windows and surrounded by other compartments, which naturally gives them a lower thermal fluctuation than in the peripheral compartments. Thus simulating a kind of “inside” underground compartments, protected by buffer zones.

With the disappearance of traditional houses, the singular processes of construction are also condemned to disappear, no longer needing to exist, by the standardization of industrial materials and increasing accessibilities.

In recent years, the interest on the recovery of vernacular constructions is emerging. The use of traditional constructive systems increases, such as the stone and adobe masonry, timber construction and mixed building techniques using a combination of timber with stone or adobe masonry. Even the use of industrial materials do not imply that architecture becomes insensitive to the references of popular architecture, as show some examples of contemporary Portuguese architecture, many times associated with a “critical regionalism”. It can be highlighted Siza's project for Malagueira neighbourhood in Évora, with obvious references to the popular construction of “Alentejo” cities, noticed in the prominent chimneys on facades that mark the succession rhythm of lots and in the presence of small courtyards.

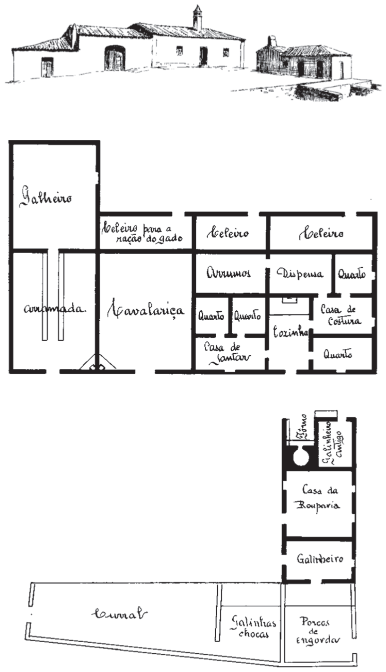

Figure 3.6. “Cascalheira” Monte, Serpa. Exterior Perspective and Plan (Veiga de Oliveira e Galhano 2000)

"The elementary quality of Siza forms and rationality behind the Malagueira plan show a strong affinity with the housing schemes that were determined by modern architecture in the first decades of the twentieth century. Siza interest on housing experiences from the twenties had already been established in his first collective housing projects for Oporto, in Bouça (1973-1977) and S. Victor (1974-1977). (...)The Évora plans as well as these previous experiences have their origin on the existence of a productive and economic nexus, manifested in repetition and compactness and in the use of (…) economic techniques of construction” (Testa, 1988). The construction systems used here also show some concern in the relation with the place, namely by the use of masonry and local craftsmanship.

In “Alentejo”, the reinterpretation of the popular construction is almost inevitable, since the cultural identity offers greater resistance to standardization. Building in northern Portugal shows a trend in the opposite direction, towards a picture of arising "progress", due to the strong industrialization. However, cultural identity does not necessarily have to be disconnected from a more contemporary language.

Souto de Moura, another influent Portuguese contemporary architect, also shows strong references from vernacular architecture in many of his works. For example in Alcanena single family house, although not in “Alentejo”, but very close to it, there are many affinities with the “Montes” previously presented. It also has a central courtyard based typology, predominantly introspective. A transposition of this same attitude but to a different context is the Bom Jesus house, in Braga – north of Portugal, of the same architect, presented in the next chapter as a case study of contemporary underground construction.

4.Underground construction in Portuguese contemporary architecture

The idea of underground building appears under the primary concept of shelter, based on the protection that it must provide. An underground construction uses the directly excavated ground to protect itself from the outside elements. It offers additional benefits when compared to conventional upper ground buildings. One of the main advantages of underground construction is energy efficiency; due to the large heat store capacity of the soil it presents a high thermal inertia. The soil temperature remains relatively constant throughout the year, near the average annual outside air temperature, so the building does not present large daily and even seasonal temperature lags.

Bury the buildings also creates high acoustic protection from the outside. This yields a more protected environment inside, which makes possible to build in places near sources of noise, where conventional buildings would be unviable or too expensive to give them the same level of acoustic insulation.

Another positive aspect to consider is the integration that this type of construction has with nature. It hardly emerges as a strange element in landscape, presenting a neutral integration.

It is however important to use an efficient ventilation, since the relative humidity is always high. The portuguese climate and soil characteristics need waterproofing of walls on excavated constructions. This creates vapour barriers, not allowing the recommended absorption / dissipation of humidity that soils rich in clay or conventional breathable walls can provide.

4.1.Case Studies of underground constructions in portugal

Underground buildings can be found in: different urban layouts (from entire neighbourhoods to isolated homes), with different uses (houses, hotels, offices, museums, libraries, etc.), and in several topographies. In relation to this last issue, it can be stated the existence of at least four types:

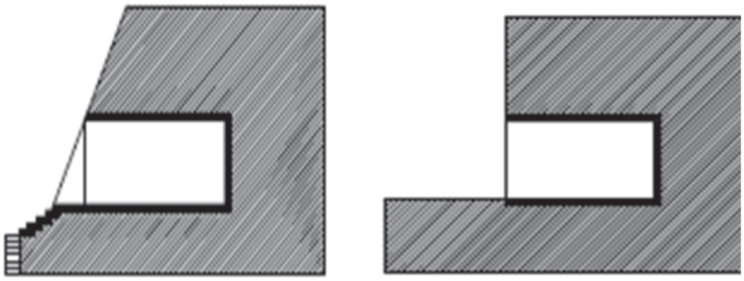

Figure 4.1.1. Sheme of type 1 construction

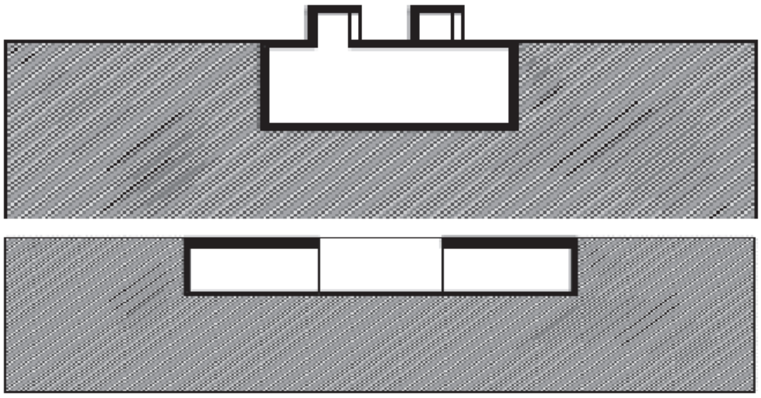

Figure 4.1.2. Sheme of type 2 construction

Type 1: Underground building in a vertical plan. In Cappadocia, Turkey, people lived for many years in underground cities. In a very mountainous region and with the enormous power of adaptation of human beings, started up to inhabit the caves and develop techniques of excavation, and thus shape their habitat. In this type of construction (Figure 4.1.1), the rock generally serves as a structural element. No example of contemporary houses of this type was found in Portugal.

Type 2: Underground building in the horizontal plan - Figure 4.1.2. There are also relevant examples in Capadoccia, such as Derinkuyu, an entire underground city from the 8th–7th centuries B.C. In portuguese territory, this type of construction is more adequate to the south geographical conditions. Although the example presented here is a house in the north: Bouçós farm house – type 2A (2007) - figure 4.1.3, in Valença do Minho, by Arch. Nuno Brandão Costa.

Type 3: Constructions integrated on terrace slopes (Figure 4.1.4), where ground and roof sometimes intermingle.

It is typical from the north portuguese territory, because of its topography. An example is Bom Jesus house in Braga - case study 3A - Figure 4.1.5, by Arch. Eduardo Souto de Moura. It is a terrace house in a city border context with two floors, with the basement floor excavated in a slope.

S. Torcato house - case study 3B – is a project by one of the authors - Paulo Mendonça. It results from the excavation of a very inclined slope, forming a sequence of ramp roofs that allow the access to the upper part of the property - Figure 4.1.6.

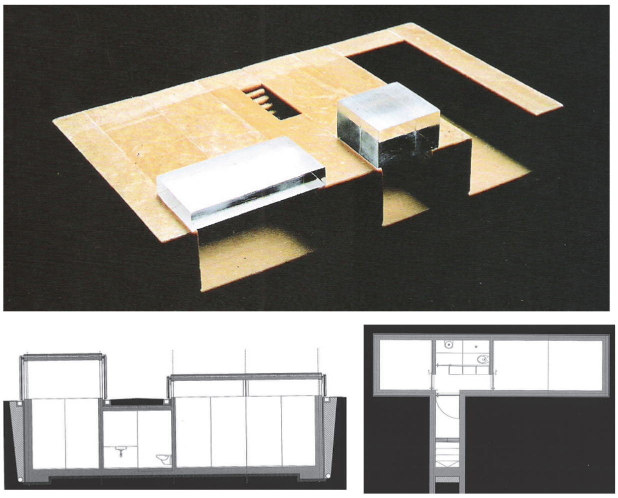

Figure 4.1.3. Bouçós farm house section and plant (Brandão Costa, 2008)

Casa Tóló in Vila Real – case study 3C - Figure 4.1.7, by Arch. Álvaro Leite Siza Vieira is a house located in a hill that instead of "fighting against nature", absorbs it. The main entrance is at the top and the house develops its program down the slope.

Type 4. Constructions that simulate artificial topographies - Figure 4.1.8. Guadix, an entire village in Granada, Spain - Figure 4.1.9, and Future Systems' house in Wales - England (1994) - Figure 4.1.10 are international examples of this type. The authors from this last example referred: "Our objective has been to minimise the visual impact of the building and to site it in a way that makes the house appear a natural part of the landscape." (Future-systems, 2009).

This type adapts to the whole portuguese territory. One example is Labruge house (1989-1994), Vila do Conde - Figure 4.1.11 - case study 4A -, by Arch. Carlos Prata. It is a small holiday house near the sea, with just 70m2. It has only one facade to the outside, facing west, to the sea.

Dune house – type 4B (2009) (figure 4.1.12), from Pereira Miguel Architects is also an example of how to minimize the visual impact near the sea, integrating the house in an artificial dune.

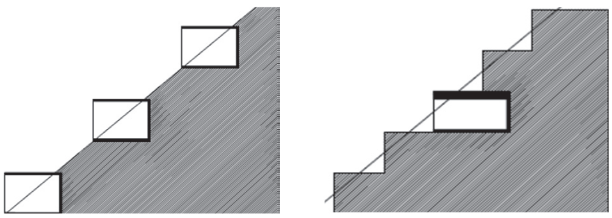

Figure 4.1.4. Sheme of type 3 construction

Figure 4.1.5. Section and view of Bom Jesus House (FG, 2009)

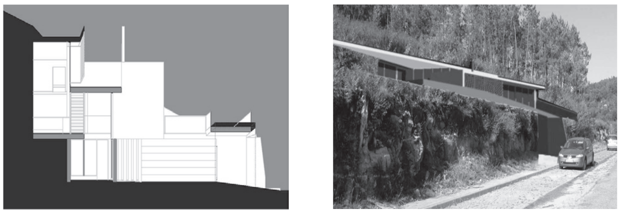

Figure 4.1.6. Section and view of S.Torcato house

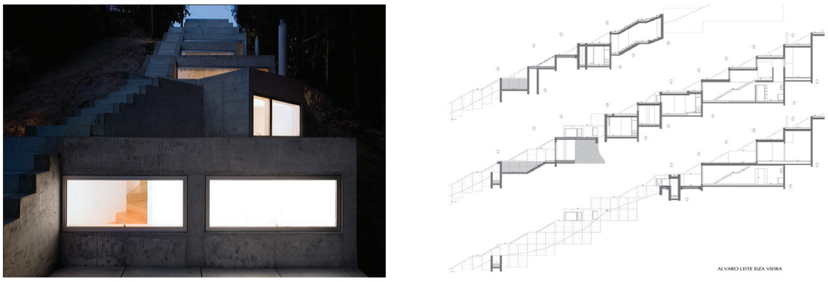

Figure 4.1.7. Front view and sections of Tóló house (FG, 2009)

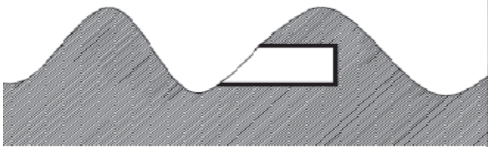

Figure 4.1.8. Sheme of type 4 buried construction

Figure 4.1.9. Guadix (Granada – Spain)

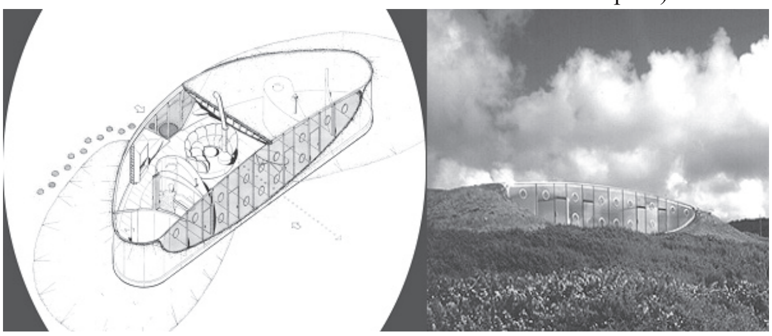

Figure 4.1.10. Future Systems - House in Wales - 1994 (Future Systems, 2009)

5. Energy efficiency in case studies

5.1. Daylighting

The visual comfort can be considered as a psychological factor that reflects the degree of satisfaction of individuals with their visual environment. The existence of natural light is essential, it is appropriate if it allows the development of visual tasks that are performed during the day. Together with acoustic and thermal comfort is one of the fundamental aspects that contribute to the overall feeling of comfort inside buildings.

Figure 4.1.11. Front view of Labruje house and section (Carlos Prata, 2009)

Figure 4.1.12. Dune house section (above) (FG 2008) and view.

There are many advantages by using natural lighting in buildings. It presents a graduate and continuous variability that helps to create a more pleasant environment than the monotonous one produced by artificial lighting.

To evaluate the natural light available inside the buildings, should also be considered the availability of natural light outside. Daylight factor (DF) describes the ratio between outside illuminance and inside illuminance, expressed in percentage. A higher DF represents more natural light available in the room. It is expressed as such:

$$DF = 100 * E_{in} / E_{ext}$$

Where:

Ein - inside illuminance at a fixed point

Eext - outside horizontal illuminance under an overcast (CIE sky) or uniform sky.

The levels of natural light indoors depends on the conditions of cloudiness in the sky, on the time of day and year, the geometrical characteristics of the building and compartments, the size and spectral-photometric characteristics of glazing, the external obstructions, and the reflective properties of interior finishing surfaces.

There are several ways to take advantage of natural light to illuminate the interior of buildings, especially in underground buildings, which by principle represent a higher difficulty in getting natural light, as there present less exposed areas available to place natural light capture devices.

In all the examples presented there are similar façade exposure then in conventional buildings, and in most cases conventional direct gain windows are explored to achieve a good penetration of natural light. These systems are especially interesting for types 2 and 3 presented, and are explored in S. Torcato house - case study 3B. Measurements of DF in the middle point of main compartments were made on the case studies and presented on Table 5.1.1. The results were satisfactory on Labruje house and excellent on Dune house.

Table 5.1.1. Daylight factors on case studies

	Bouçós house – Type 2A	Labruje house – Type 4A	Dune house – Type 4B
DF measured on the middle of compartment	1,2	2,9	5,1

In what concerns the south vertical openings, shading devices should be placed horizontally. In high windows it is recommended to have overhangs above the line of sight, dividing the glazing in two sections, one on top, called "daylight opening" and one at bottom, the "open vision". The top should have a high reflectance finishing: such as glass mirror or highly polished metals to be more efficient. These can be used for types 1, 3 and 4. The Labruje house – 4A and the S. Torcato house 3B uses simple forms of this system – external venetian blinds and fixed overhangs. North vertical openings don’t need shading devices, and other orientations should be avoided, but when it is necessary they should present vertical shading devices.

Another option is the skylight. It consists of an opening located in a horizontal or slanted roof. The skylights allow natural light to reach the spaces below; however it is necessary that the building has the roof in direct contact with the outside. This system was explored in Bom Jesus house – type 3A and Labruje house – type 4A.

But even in more deep underground solutions, there are devices that can allow the entrance of natural light. Lighting ducts are the most used system to capture natural light in these cases. The lighting ducts (and its variants) allow the capture of daylight and their conduction to areas and interior spaces of buildings not directly connected to the outside environment. Generally, the interior surfaces of lightning ducts are coated with materials with high reflectance in order to direct and spread the natural light "down" with some effectiveness, including mirrors and prismatic components.

From a previous study by the author (Mendonça, 2005), it could be concluded that higher values of daylighting does not mean better overall energetic efficiency. The central question in this issue is to decide between direct gain strategy and indirect gain strategy:

•Direct Gain - the estimated values for thermal gains are usually higher in a direct gain strategy, but the temperature and glare due to the excessive solar radiation penetrating occupied areas can be a source of discomfort. On the other hand, the excessive solar exposure can lead to furniture and other equipment degradation. Additionally, with this strategy it is normal to have a great asymmetry in the radiant temperature between the exposed glazing and the interior walls, which is also a cause of discomfort. These facts can lead the building occupants to constantly operate the existent shading devices and, consequently, block the required thermal gains, as well as the natural illumination;

•Indirect Gain - in spite lower thermal gains estimated values, an indirect gain solution can, more effectively, guarantee that the forecasted values are closer to reality, since there is a more efficient control of the thermal gains. Then, the strategy chosen for the proposed design was an indirect gain strategy.

5.2. Thermal efficiency

Thermal fluctuations in the ground are minimal, guaranteeing not just a reduction of daily, but also of annual thermal lags. This is due to the great thermal inertia assured by the thickness of soil. This means that almost no thermal insulation is needed and the needs for mechanical equipment are reduced, especially for cooling. In cases where thermal gains are needed, a greenhouse can be created in direct contact with the construction, allowing heat to be later retained inside the building – this system was explored in S. Torcato house bedroom areas – type 3B. This type of solar passive heating works as an indirect system (Figure 5.2.2), with lower theoretical gains then direct gain systems (Figure 5.2.1) (used in all other case study types presented). However it guarantees a better compromise between thermal and natural lighting comfort.

As there is no direct radiation penetrating the compartment – there are no need to close shutters for lighting comfort when there is occupancy, what could compromise project predicted gains (Mendonça, 2005).

The acoustical insulation is also assured by the existence of buffer zones, what is intrinsic to indirect gain systems.

This system pretends also to explore a greater flexibility in the use of interior spaces, allowing a 30% increase in flexibility, when compared to a conventional system, as it can be seen in Figure 5.2.3. This system was explored on S. Torcato house – type 3 B.

Measurements of temperature were made on Bouçós, Labruje and Dune house, between March and June 2009.

Results of these measurements are presented on Table 5.2.1. As it can be seen, ΔT (daily thermal lags) on the interior were just between 1 and 2,5 ºC, what is specially relevant on houses located more far from the sea, what was the case of Bouçós and Dune house. Labruje house is very close to the sea, that's why the exterior ΔT was very low.

Table 5.2.1. Measurements of temperature on case studies

		Bouçós house – Type 2A Temperature (ºC)	Labruje house – Type 4A Temperature (ºC)	Dune house – Type 4B Temperature (ºC)
exterior	min	12	16	8
	max	27	20	18
	ΔT	15	4	10
interior	min	16	18	13,5
	max	17	20	16
	ΔT	1	2	2,5

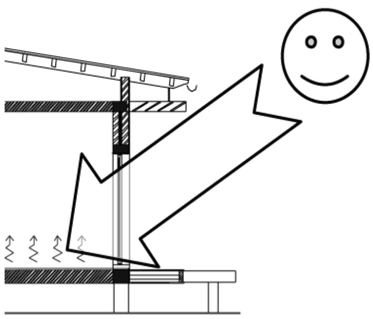

Figure 5.2.2. Indirect gain scheme

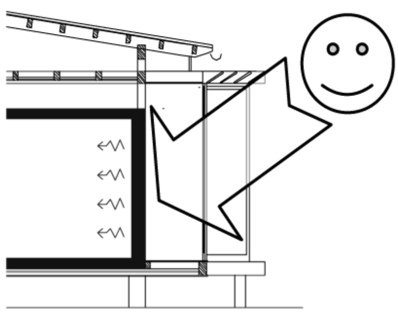

Figure 5.2.1.Direct gain scheme

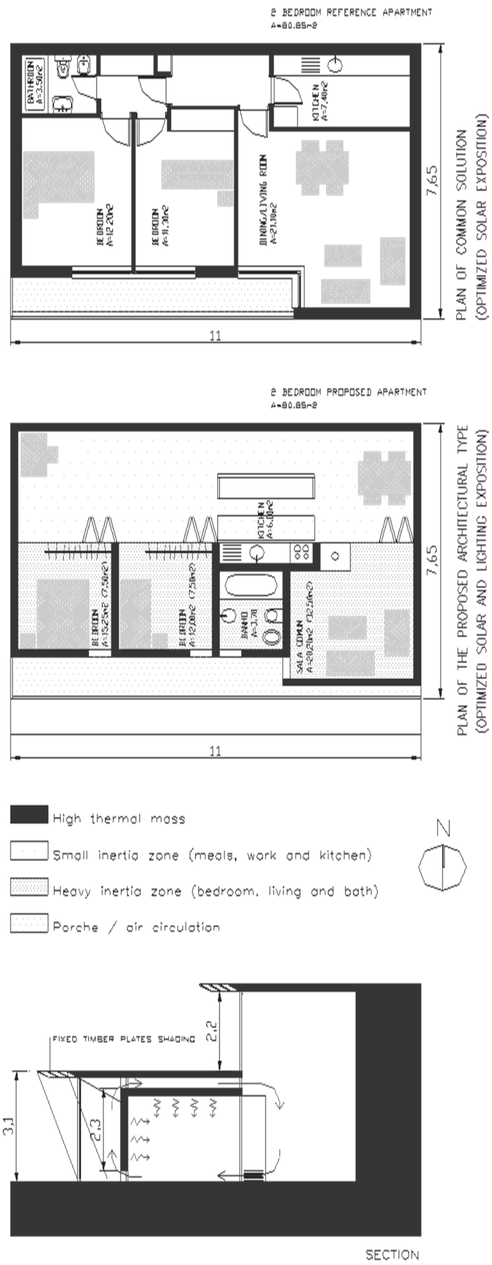

Figure 5.2.3. Indirect architectural typology – comparison on therma inertia and flexibility with a conventional dwelling of the same area.

5.3. Relative humidity

Humidity is a major problem on underground buildings. To prevent problems of durability of materials used inside and on the air quality, ventilation strategies should be used for reducing the moisture content in the interior environment. However, despite the high humidity, it does not mean that there is cold condensation in walls, because these cool very slowly (due to high thermal inertia) assuring these don't easily reach dew point.

Apart from a good ventilation, the best way to assure a low relative humidity is the election of a soil type that has significant amounts of clay (35% or more). This kind of soil is very rare in the portuguese territory, so the excavated buildings are in general inserted on rock soils. In this context, and before proposing an underground construction in Portugal, it is recommended to make a study of groundwater level of the site, what must force to use materials like asphalt for waterproofing. In this case the excess of humidity should be expulsed in the form of water vapour. It is therefore very important that the other surfaces, including walls, roofs and windows can breathe, and to use materials to facilitate this phenomenon. Sheet metal, waterproof concrete or windows without ventilation grids are solutions to avoid the other elements that confine the underground space. It should be considered the use of some vapour permeable façade and vapour absorptive interior dividing walls. In the S. Torcato house – type 3B, adobe walls and ceilings are used. The lighting and solar passive gains systems, mentioned above, may also function to create air pressure differences over the housing (solar chimneys and other openings). In the Bouçós house – type 2A, the high opening ventilation allow the dissipation of humidity. Relative humidity was measured in Bouçós, Labruje and Dune houses, and in all cases it was between 60% and 70%, what is similar to conventional portuguese buildings, as presented by Mendonça (2005).

6. Conclusion

The advantages and disadvantages of underground constructions were discussed. Some existing examples of North Portuguese contemporary houses were presented as case studies. Some of these examples were measured regarding thermal comfort parameters. The results were used for optimizing an underground housing unit project, S. Torcato house, presented here and projected by one of the authors. It pretends to be a future model occupancy strategy for urban sprawl territories, such as the existing in the north portuguese territory.

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المساكن المعاصرة المشيده تحت الارض في شمال البرتغال

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الملخص:

علـى مـر العصـور وكمـا في اقـدم المستوطنـات البشريـة المعروفـة –كاتـال هيـوك في هضبـة الاناضـول- بحـث الانسـان عـن المـاوى تحت الارض وذلـك بـا استخـدام الطبيعـة نفسهـا او استلهامها كنمـوذج للمبـاني التـي يشيدها .

يتميـز شمال البرتغالتنـوع استخدامات الاراضي وصعوبة توفير البنية التحتية والطـرق بصورة ملائمة للبيئة وذلك لاسباب عديدة كالتالي:

التبايـن الحـاد في طبيعة السطح (الطبوغرافية) انقسـام الاراضي الزراعية لمساحات صغيرة نتيجـة انتقال الملكية المتكرر وانتشار الصناعات الصغيره عالية الكثافة في العماله .

وقد زاد من هوه المشكلة خلال الثلاثون سنة الماضية الاعتماد على الوسائل الخاصة للنقل .

الا ان الوضـع الاقتصـادي يمـر بتحول جـذري حاليا حيث انتشار البطالـة بسبب اغلاق الصناعـات الصغيرة مما ادى الى ضرورة الاعتماد على النفس في المعيشة–مثل تربية الدواجن بصورة فردية.

كمـا ظهـرت اعاقـات في الارض الزراعيـة مثل انتشار المبـاني المتنـاثـرة وصعوبة الوصـول للاراضي الزراعيـة المحصورة .

تتفاقم هذه المشكلة خاصة في المنحدرات الجنوبية مما ادى الى عدم تحقق امال زيادة الكثافة السكانية .

لهـذا تم طـرح استراتيجيـة لمواجهة هذا الوضـع القائم وذلك مـن خلال خطة مقترحـة لدمج المساكن (تحـت الارض) في المنحدرات المدرجة واستغلال التربة اعلى المساكن والمساحات المتاخمة لها مباشرة للزراعة .

كما ان هذه الطريقة تقلل ايضا من الوقع البصري للمباني على المناظر الطبيعية .