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Living Envelopes for Buildings – A Historic Parallel

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Living Envelopes for Buildings – A Historic Parallel

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Abstract. According to Daniel Libeskind 'Architecture is not based on concrete and steel and the elements of the soil. It's based on wonder.' A building is a sculpture at a territorial scale. Integrated in the environment it may bring added value to the landscape (as in the case of the Sydney Opera House that became not only the symbol of the city but also of Australia). In a dry definition, a building is a plant: it shelters scheduled activities and interacts with the natural and built environment in a manner that led to comparisons with the medical world: we have building pathology, sick buildings, building skin, breathing structures etc. From the architects' point of view, a building is about space. From the engineers' point of view, a building is about performances. From the users' point of view, a building is about well-being (which is an immaterial notion). The building envelope has always been somewhere between material and immaterial: a combination of fashion and technology. In the past decades it has been analysed according to the essential requirements and classified in types and categories. As the necessity of preserving the planets' resources increases, the need to impose new requirements on the buildings increases as well as, according to modern researches, the most important energy consumers are the buildings and their users. In this context, the building envelope gains some new responsibilities and roles:
- to save energy, to produce and (when appropriate) to harvest energy;
- to diminish the type and amount of urban pollutants and to restore the quality of the micro-climate of the environment
Strange as it may seem, current trends in architecture turn to perennial principles of design that have always been taken into consideration in the traditional architecture or throughout history.
Living envelope systems are in fashion, as the benefits of plants spin from providing better air quality by decreasing heat island effects to providing food in urban farms and from saving energy in buildings to preserving the natural environment. Buildings designed with living envelopes are millenary solutions. The paper focuses on making a parallel between contemporary architectural approaches and historic approaches regarding the building envelope.

1. Introduction

Living envelopes refer to roofs and facades with living plants as finishing systems that act as interface with the environment. Sometimes described as "green" roofs and facades, they should not be mistaken with the concept of "green architecture", that represents "an approach to building that minimizes harmful effects on human health and the environment" [1].

The contemporary trends in bioclimatic and "green" architecture emphasize the use of plants on the facades or roofs as means of saving energy, improving the microclimate in and around the building and diminishing the urban heat island effect. However, the use of plants as a component of the building envelope is not new. In fact, it goes back some thousands of years. In different moments of history although the same principles were used, the aims were – or may have been – different and the 'roles' played by the vegetal layer(s) changed or increased as new requirements were imposed to the building envelope.

2. Types of living envelopes for buildings yesterday and today

2.1. Living sloped roofs

Sloped roofs with planted layers have commonly been used in climates where snow and rain are common. In Northern Europe the grass grows above the slopes covered with several layers of birch bark. The construction system of the roofs (that can be tracked back to the Viking period) included a protection with sod. Figure 1 presents what is supposed to be the oldest farm assembly covered with earth and sod in Europe, dating since 1193.

Figure 1. Earth covered farm homes in Keldur, Iceland. [15]

The vegetal layer was cut from the pastures. The 'tiles' were about 30 cm wide. The vegetation layer plays a double role: to ballast the roof shingles against wind and to provide additional thermal insulation (the sod and vegetation layer representing an important extra-thickness) [2]. The installation of the vegetation tiles on the roof was almost concomitant with the installation of the birch shingles, in order to provide the best adhesion. The first vegetal layer is with the vegetal side downwards so that the dry grass layer protects the shingles against humic acids within the earth substrate. The second layer is provided with the vegetal layer upwards. The roots would penetrate both layers. To ensure the stability of the slope, logs with a diameter of 10 - 15 cm were installed at the roof edge with the role of a guard.

Nowadays the "living" sloped roofs are a landmark of Northern traditional architecture on both sides of the Atlantic and represent a touristic attraction, not only a roof protection.

2.2. Living roof top gardens

What we usually refer to as rooftop gardens can be tracked back in time as far as Babylon: the famous Hanging Gardens (Figure 2), one of the seven wonders of the ancient world, (seem to) have been described by Ctesias in his work Persica (now lost) sometime in the III-rd Century B.C. [3]. About four hundred years later Diodorus Siculus copied the description that was eventually transmitted to us: 'The Garden was 100 feet long by 100 wide and built up in tiers so that it resembled a theater. Vaults had been constructed under the ascending terraces which carried the entire weight of the planted garden; the uppermost vault, which was seventy-five feet high, was the highest part of the garden, which, at this point, was on the same level as the city walls' [4].

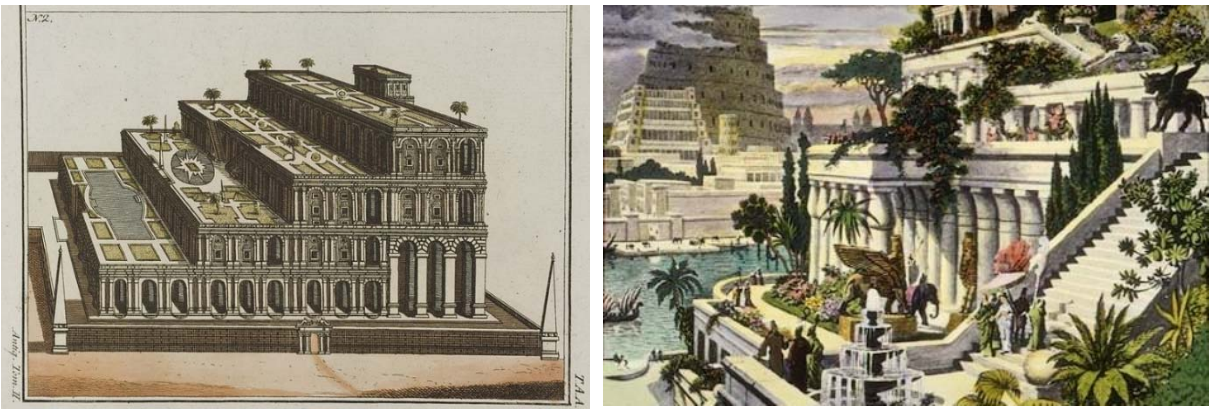

Figure 2. The Hanging Gardens of Babylon

Robert von Spalart in XIX-th Century (left) [16]

Martin Heemskerck, XVI-th Century (right) [17]

Strabo describes the Gardens as follows: "Babylon, too, lies in a plain; and the circuit of its wall is three hundred and eighty-five stadia. The thickness of its wall is thirty-two feet; the height thereof between the towers is fifty cubits; that of the towers is sixty cubits; and the passage on top of the wall is such that four-horse chariots can easily pass one another; and it is on this account that this and the hanging garden are called one of the Seven Wonders of the World. The garden is quadrangular in shape, and each side is four plethra[1] in length. It consists of arched vaults, which are situated, one after another, on checkered, cube-like foundations. The checkered foundations, which are hollowed out, are covered so deep with earth that they admit of the largest of trees, having been constructed of baked brick and asphalt — the foundations themselves and the vaults and the arches. The ascent to the uppermost terrace-roofs is made by a stairway; and alongside these stairs there were screws, through which the water was continually conducted up into the garden from the Euphrates by those appointed for this purpose. For the river, a stadium in width, flows through the middle of the city; and the garden is on the bank of the river" [5]

Some legends say that the Gardens were built by Ninius, the founder of Babylon and Niniveh, for his wife Semiramis; others say that Semiramis built them in her five years' reign, between 810 and 805 B.C. According to other stories, the Gardens were built as a gift from king Nebuchadnezzar II for his wife Amyithis, sometimes in the VI-th Century B.C. Princess Amyithis, daughter of the king of Medes, was married to Nebuchadnezzar to create an alliance between Mesopotamia and Medes. As the landscape from her homeland was very different from the Babylonian one, flat and dry, her royal husband tried to make her feel less depressive by building a terraced construction that accommodated a garden. Some historians doubt that the Gardens ever existed. According to Stephanie Dalley [5] the Hanging Gardens were built not by Ninius, Semiramis or Nebuchadnezzar but by Sennacherib in the VII-th Century B.C. and not in Babylon but in Nineveh. It seems that there was a tradition of building gardens within the cities in ancient Mesopotamia, as Tiglath-pileser I built, in the XI-th Century B.C. a palace and a garden in Nineveh: 'beside that terrace I planted a garden for my royal leisure. I dug a canal from the river Khosr and [directed its water] into that garden. I brought the rest of that water into the outskirts of the city for irrigation. Within that garden I built a(nother) palace' [6].

It is worth mentioning that ancient Mesopotamia had an advanced system of water management that included canals, weirs, dams, bridge-like aqeducts, all built by Sennacheribs' engineers and discovered, registered and mapped in the early thirties by scholars in the field of Assyriology.

[1] One plethron equals 100 feet - www.britannica.com/science/plethron

According to Diodorus' description 'the roofs of the vaults which supported the garden were constructed of stone beams some sixteen feet long, and over these were laid first a layer of reeds set in thick tar, then two courses of baked brick bonded by cement, and finally a covering of lead to prevent the moisture in the soil penetrating the roof. On top of this roof enough topsoil was heaped to allow the biggest trees to take root. The earth was leveled off and thickly panted with every kind of tree. And since the galleries projected one beyond the other, where they were sunlit, they contained conduits for the water which was raised by pumps in great abundance from the river, though no one outside could see it being done' [7]. Interesting enough, the materials and the structure of the roof are – in principle – correct, as there is 'reinforced' tar and lead for hydro-insulation and root barrier (preventing the root penetration within the structure of the roof), as well as a system that provides water for the plants. Today these structures would be called roof-top gardens.

The science of building hanging gardens was lost in time. Somehow, in the nineteenth century it was re-discovered, not with the aim of constructing a garden on top of a ziggurat but to prevent cheap roofs of low cost residential buildings to be destroyed by fire, in the newly appeared urban areas that provided workers for the expanding industries of the period.

The idea belongs to a German roofer – Koch – who decided to provide a fire protection of the tar roofs, with sand and gravel [8]. Shortly, seed carried by wind or birds was colonized, leading to what we define today as extensive green roofs, biodiverse roofs or brown roofs (Figure 3).

Figure 3. Lend Lease Biodiverse Roof, [18]

In the early thirties the idea of building rooftop parks was highly appreciated and the 'hanging gardens' were re-invented. Probably the best example of a historic rooftop garden is the Rockefeller Center in New York (Figure 4), designed by Raymond Hood (1930 – 1939). It seems that the waterproof membrane is still the original one [9], despite the fact that the life span of such a building component is supposed to last about 15 years, if well designed (the appropriate structure and material), installed and protected.

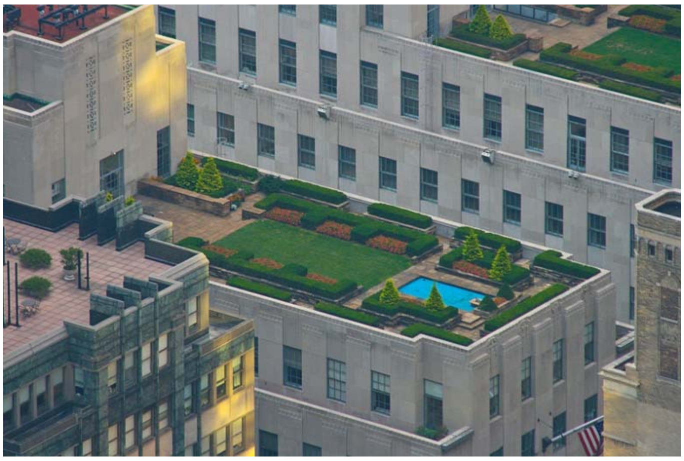

Figure 4. The rooftop Gardens of Rockefeller Center. Photo: Jwilly77 [19]

The contemporary bioclimatic architecture promotes the use of green roofs – intensive or extensive – not only for the image that can be seen from the surrounding buildings but also as a means of diminishing the urban heat island effect, a problem rising from the increasing urban pollution. One example may be the rooftop garden of the Chicago City Hall (Figure 5), designed by William McDonough & Partners and completed in 2001.

Figure 5. The rooftop Gardens of the Chicago City Hall. Photo: courtesy Celia Haven

An interesting fact about this particular roof is that half of the building is occupied by the City Hall and half by Cook County's administrative offices (with a tar roof). The green semi-extensive roof was installed on the roof of the City Hall. Temperature has been monitored on both parts of the roof of the building the green roof and the Cook County roof. According to the Department of Energy 2004 [10] Federal Technology Alert: Green Roofs. DOE/EE-0298, Washington, D.C. 'On an August day in the early afternoon, with temperatures in the 90s, the green roof surface temperature ranged from 91 to 119°F (33 to 48°C), while the dark, conventional roof of the adjacent building was 169°F (76°C). The near-surface air temperature above the green roof was about 7°F (4°C) cooler than that over the conventional roof.'

2.3. Living facades

Buildings with planted successively receding tiers fall in principle between the roof-top/green gardens and the buildings with living/green facades, resembling more with the Hanging Gardens than with

Kochs' roof protection. In fact, roofs or facades, they are both components of the living envelope, interacting with the natural and anthropic environment.

A very good recent example is given by the Bosco Verticale (Vertical Forest) buildings in Porta Nuova, Milan, designed by architect Stefano Boeri (Figure 6), finalized in 2014. According to the Stefano Boeri Architetti [11] site, the two residential towers host '800 trees (each measuring 3, 6 or 9 meters), 4,500 shrubs and 15,000 plants from a wide range of shrubs and floral plants distributed according to the sun exposure of the facade. On flat land, each Vertical Forest equals, in amount of trees, an area of 20,000 square meters of forest'. Although the terraces have been designed like rooftop gardens, to withstand the weight of the substrate (soil) and the trees, the overall aspect is of a green façade. Water and nutrient management must be taken care of, to make sure the plants stay alive.

Figure 6. Bosco Verticale in 2015: June (left) [20] and November (right), photo: Ana-Maria Dabija

Wherever positioned on the envelope of the building, the living components play an important part in providing a better air quality as well as in the image that they offer to the city or the neighbourhood.

Living green walls are not new inventions either: plants that take over the walls, fences, posts, climbing on the surfaces that they can cling to, are a landmark of old buildings or historic neighbourhoods. While with a familiar, nostalgic or romantic aspect (Figure 7), the buildings spontaneously covered in ivy or vine can give rise to deterioration of the envelope: on one hand the process of evapo-perspiration of the plants may lead to the increase of the humidity of the wall, with undesired consequences of mould growth, while on the other hand the wall finishing may be compromised by the plants' clutching systems.

Figure 7. Buildings in the old part of Bucharest, Romania. Photos: Ana-Maria Dabija

In order to benefit of the advantages provided by the climbing plants – shading, air quality – smart detailing conducted to a sub-category of ventilated façade systems: the green / living facades: between the plants and the adjacent wall, a layer of air is interposed. The green facades principles rely on the natural growth of the climbing plants. Their roots are in the soil and their hosting elements are not the walls but built structures that prevent them from clinging onto the façade finishing systems, as in the example of the Consorcio Office Building in Chile (Figure 8). According to the season, the façade looks different: green in the summer, red in the autumn (as the leaves turn red and gold).

Figure 8. Living green façade of the Consorcio – Chile Office Building.

Architect Enrique Browne Arquitectos, Landscape: Juan Grim, Maria Angela Schade

Photos: courtesy of Guy Wenborne

In the case of this building, the concept is a double façade facing West, consisting of a glazed curtain wall with a screen-structure in front, that plants can climb onto. The distance between the glazed part and the screen accommodates maintenance circulation and the necessary area and volume of growing substrate for the plants (Figure 9). Leaves shade the glass in summer while in winter the sun rays passing through the curtain wall provide passive solar gain for the interior.

Figure 9. The double façade of the Consorcio – Chile Office Building, photos: courtesy of Guy Wenborne

Living walls are closer to the ventilated façade systems as they consist of panels supported by a structure that is attached to the building. The panels include the plants and the growing medium. These systems are not new either: the inventor of the living wall system was a landscape architect and a University professor, Stanley Hart White. In 1937 he patented the 'Botanical Bricks' and in 1938 the 'Vegetation Bearing Architectonic Structure and System' [12] where the patent aims to 'provide the architectural profession and related industries with an efficient and inexpensive method and means for utilizing a novel medium for ornamental and useful architectonic construction, in various forms of units and compounds having vegetation-bearing surfaces'.

These containers with plants require knowledge and care provided by botanists and are anything but *inexpensive*. They require attention and care, detailing and maintenance: water and corresponding nutrients must be provided through appropriate pipes and equipment. The choice of plants is an art itself and the result is vertical landscape architecture. The living walls represent a means to improve the quality of the environment while offering a vibrant, fresh and permanently changing image to the city (Figure 10).

Figure 10. Living wall façade of a building in Madrid designed by botanist Patrick Blanc Photo: [21]

Green urban structures are assembled in many cities of the world (Figure 11), not linked to buildings but close to Stanley Hart Whites' vision of the invention defined as a method 'for producing an architectonic structure-of any buildable size, shape or height, whose visible or exposed surfaces may present a permanently growing covering of vegetation' [12].

Figure 11. Detail of the Umeda Sky Building Square, Osaka. Photo: Ana-Maria Dabija

3. Strong and sensitive aspects of the living envelopes.

While in Mesopotamia the Hanging Gardens were built for the beauty of the assembly, in time the living envelopes proved to provide more advantages than the aesthetic image. Plants accomplish the following:

- convert water and carbon dioxide into oxygen through photosynthesis;
- clean the air from pollutant gases produced by cars or industries;
- diminish the heat island effect by the process of evapotranspiration that lowers the temperature of the environment [13];
- enhance urban biodiversity, providing the appropriate living conditions for bugs and birds.

In respect with thermal protection and energy savings, the plants and the corresponding structures diminish the costs for heating in winter and cooling in summer (as the layers of growing substrate and plants provide extra thickness and in consequence extra thermal insulation). The living walls with falling leaves provide shading in summer; during the winter season, as only the stalks survive, the sun heats the supporting wall thus increasing the surface temperature of the latter.

The green roofs have a contribution to the stormwater management, as the leaves, roots and growing media retain or slow down the rainwater, thus contributing to the safe functioning of the urban drainage systems. Green roofs are heavier structures, thus contributing to a better sound insulation of the spaces underneath them. For all the above-mentioned reasons, in many countries urban and administration policies promote or require the use of green structures for building envelopes, at least to balance the displaced vegetation on the building site.

Sensitive aspects in designing buildings with living envelope assemblies relate to specialized fields:

- it is mandatory to take into consideration from the beginning of the design process the type of green roof or living wall: extensive roofs have a thickness of the growing substrate of 2cm to 10 cm while roof-top gardens may have plants that require 70 cm to 120 cm for growing substrate. The structure of the building must be calculated accordingly;
- plants need to be watered and fed, therefore appropriate equipment and specialized maintenance should be provided, implying supplementary costs in construction and use of the building;
- the choice of plants as well as their nursing and replacement, when necessary, is carried out by specialists (botanists) throughout the existence of the plants, thus leading to maintenance costs that must be considered from the beginning;
- appropriate architectural detailing as well as responsible installation of the supporting layers (waterproof membrane, necessary anchorage and attachments, draining systems etc.) must be carried out, in order to prevent root penetration, stalk clutching, water leakage or stagnant water on sidewalks that can result in accidents of by-passers.

4. Conclusions or 'what about tomorrow'

As previously stated, the living envelope systems functions have evolved from leisure to more technical: energy saving, thermal and acoustic insulation, preservation of natural environment. In recent years a new function makes its way, related to 'what' and not to 'how' we cultivate on the roofs. What began as a park, nearly three millenniums ago, is heading to a more pragmatic approach: providing food for the urban population. Urban farms are not utopic any more but already exist in practice. The next generation concept is the vertical farm, promoted by visionary architects. However, the principle of vertical farming is not new either: it was launched in 1909 by a drawing in Life magazine and it was first used as a concept of a multi-storey building for indoor cultivation, in 1915, by Gilbert Ellis Bailey who created the term "Vertical Farming" [14]. And from here, another parallel begins.

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