The Green Envelope Efficiency on Office Buildings

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Abstract: In the past several years the whole world targets the Green Strategies and Green Infrastructure Techniques. Although it has a different types and technologies, each one of them could be applied to specific functions and spaces.

Depending on that, they apply it not only in new designs but also in the existing buildings. Therefore they start to use Green Walls and Green Roofs to protect building envelopes, maximize the thermal comfort, and minimize the need of using H-VAC which lid to minimize energy consumption and also to be as an environmental solution to compensate the shortage of horizontal green spaces which will improve the outdoor air quality and reduce the urban heat island effects.

From this point the paper will discuss how to integrate the green strategies with green infrastructure techniques in existing buildings envelope through using Green Walls and Roofs in different orientation (East, South and West) and measuring its effect on energy consumption and CO2 emission by using DesignBuilder simulation program. Also the paper will discuss how these techniques will effect on water consumption and reducing the urban heat is land effect.

The paper methodology will be through literature review about green infrastructure techniques generally and green envelope techniques specifically, then it will discuss its methods and effect through analytical example, to be ended with the practical part which will shows how the Green Walls and Roof application on office building space could be used as a one of green infrastructure techniques, protect the space envelope and finally how it reduce the energy consumption and CO2 emissions through using DesignBuilder simulation program

Keywords: Green Infrastructure; Building Envelope; Plantation Skin; Green Design Techniques

1. Introduction

The Green Areas and Sustainable Architecture are very important to the ECO-System and the people live around them. However much of them has been degraded according to human actions to words the eco system. There are many phases to reach sustainability; first to stop abuse and think green, second change the idea of construction buildings to green buildings, third reusing and recycling, finally monitoring and maintenance. The main aim of the paper develops is how to compensate the lake of green spaces by using green infrastructure techniques in building envelop. How to build with reduction of damaging environment, maximize the indoor quality, saving energy and integrating natural vegetation with building construction. The importance of green techniques is how to maximize indoor and outdoor quality and compensate the lake of green spaces.

Different references give different definitions to green infrastructure; [1] states that "Green infrastructure means different things to different people depending on the context in which it is used" For example, some people refer to trees in urban areas as green infrastructure because of the green benefits they provide, while others use green infrastructure to refer to engineered structure that are designed to be environmentally friendly.

1.1. Problem Defintion:

The human beings are the latest organism on earth. The industrial revolution was in 1750. During 350 years of industrial activity humanity effected the eco system by CO2. Many green spaces are disappearing. Second; fragmentation which is defined "the division of the farmland into a collection of scattering lots". "Fragmentation increases edge habitat and the isolation between patches while reducing the number of natural plant and animal species" [1]. Third thing is the degradation of water resources. Green infrastructure provides not only storm water

management, but also flood mitigation, air quality management, energy consumption and more. The Final point is in the weakened ability of nature to respond to change.

1.2. Paper Methodology:

The methodology will be through literature review about green infrastructure especially green walls, then analytical example and finally will be a case study with an experiment through design builder.

2. Green Infrastructure Tachniques

Green infrastructure can provide climate change mitigation and adaptation through many things; it can help to reduce ambient heat and flooding in urban areas due to the cooling effect of trees, the implementation of sustainable urban drainage system (SUDS) in the right location plays a vital role in combating flooding, a higher percentage of green cover in urban areas reduces the air temperature, trees and other vegetation remove CO2 from the air, increasing environmental quality and quality of place encourages more people to travel sustainably through green spaces linkages, finally its linkages enable continued spaces diversity [2].

There are many techniques of green infrastructure; green roof, green wall, down spout disconnection, rain barrel, permeable pavement, vegetated swale, rain gardens, infiltration trench, and urban fortes and restored wetlands. Each one of them has its benefit. Some of the techniques achieved all restoration benefits while others achieved only few. The benefits are; slower rate of runoff, infiltration, retention, detention, water quality control and reduced CSO frequency.

2.1. Green Walls:

Green walls is a type of green infrastructure techniques; Green Walls with the another name Vertical Gardens is the term of used to refer to all form of vegetated wall surfaces and it divided into Living Walls System (LWS) and Green Facades Systems (GFS), [3] Green walls can be categorized into three types of common systems: panel/modular systems, tray systems and freestanding walls. A sound understanding of all three types will help to identity which one is best-suited for the project.

There are two types of green walls or vertical vegetated facades; Living Walls System (LWS) and Green Facades Systems (GFS) [3]

2.2. Green Facades:

It consists of climbing plants (growing directly on a wall or in specially designed supporting structures). The façade full coverage take from three to five years (Fig. 1). [3, 4]

Figure 1: Climbing Vegetated Facades [5]

It installed by two types of structure systems; [4]

1- Modular trellis panel system.
2- Grid and wire-rope system.

2.3. Living Walls:

It is more specific than for climbing façades, it composed of re-vegetated panels, vertical modules that are fixed vertically to a structural wall or frame. [3]

The final installation generally offers a more flexible solution in terms of aesthetics and functionality. The techniques are based around two main groups (though hybrid solutions do exist).

Hydroponic- soil less (Fig. 2): This method takes benefits of the fact that plants do not require soil to grow. Soil simply offers mechanic root support for the plant and it is only water (along with the minerals stored in the soil) that is necessary (in addition to light and carbon dioxide from the air).

Substrate- soil based (Fig. 3): These systems typically use containers that are built to existing walls. Planting is sustained by soil-based substrates similar to those used in green roof installations; utilizing a lightweight mixture of recycled materials containing the right balance of nutrients with a free-draining.

Figure 3: Hydroponic (soil less) system [5].

Figure 2: Substrate (soil based) system [5].

2.4. Benefits of Green Walls:

Installing green façades and living walls can effect in many profits to the environment, buildings and human prosperity. The next list show more detail on what benefits can be realized with urban greening solutions in general and how these are achieved; [6]

a. Air purification: During the morning plants extract carbon dioxide, carbon monoxide and many other toxins from the air during photosynthesis, causing in significant reductions in CO2 levels in well vegetated urban areas.
b. Noise reduction: Planted surfaces have low noise reflection and high absorption characteristics. .
c. Dust suppression: Large areas of greenery help to destroy dust particles; improving air quality. This may lead to a saving the respiratory system. There has been much focus in England recently on reducing PM10 particles to meet EU regulations.
d. Heat reduction: Urbanized areas have a higher average temperature than countryside. Increasing vegetation in city, or urban valleys, provides cooling of trapped air and reduces reflected heat. Tests have shown temperature differences of up to 17^{o}C between hard and vegetated surfaces in the same location. [5]
e. Health and wellbeing: Plants and greenery can provide calming effects on people whilst having a positive impact on stress relief. Studies have shown that simply having a view of greenery increases productivity and patient recovery rates in medical places.
f. Biodiversity: By using range of plants a green wall can significantly increase the number and variety of insects and birds in a given area, helping to return a more sustainable ecosystem in urban environments and fill part of the taken land.

g. Water management: Increasing the coverage of vegetation can reduce storm water management for a building. This is especially useful in older urban areas where excess storm water is shared with wastewater systems. More advanced solutions can harvest rainwater for green wall irrigation, excluding the need for a fresh water supply.

h. Aesthetics: Vegetated surfaces are generally considered aesthetically pleasing; they can provide happiness and stress relief for any one look at it

i. Urban farming: The introduction of vertical gardening techniques significantly increases available space for growing food in urban environments.

j. Building protection: Green walls help reduce UV damage to surfaces and can protect a building from wind, weather and temperature fluctuations, prolonging the life of the structure. These factors could offset maintenance costs of green wall. [5]

3. Analytical Examples

The following analysis shows how Vertical Greening Systems effect on energy consumption and improve the surrounding environment in the building that the main street axis forced it to be oriented to the south which led to maximize the heat gain in the main façade and shows how the designer choose to solve this problem through isolating the façade from direct radiation using the Green Wall instead of using H-VAC system to achieve the human comfort.

3.1. Consorico Santiago Building:

It also called a Consortium Building Santiago; the building is located in Santiago, Chile which means it's located in a Mediterranean Climate with hot, dry in summer and milt, moist in winter. It designed by Enrique Browne and Borja Huidobro and it's oriented to south because of the main street axis. [7]

According to the building orientation and the climate condition the Green Wall (GW) has been installed on north and west facades with area about 2700 m2 (Fig. 4)which equivalent to the area of the surrounding houses gardens. [8]

The Green wall System Overview: it has been conceived with double vegetated façade and it installed on a free structure in front of the building skin with air gap distance 1.4m, the system is made up of two elements; trellis and planter boxes and the installation has been located above the first three floors as they are protected from sunrays and heat gains by street trees (Fig. 5). [7]

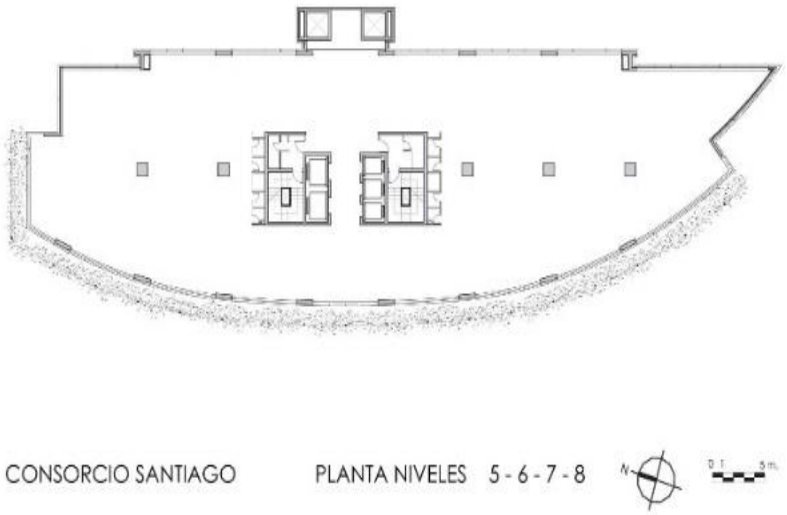

Figure 4: Typical floor of Consorico Santiago Building showing the GW location. [9]

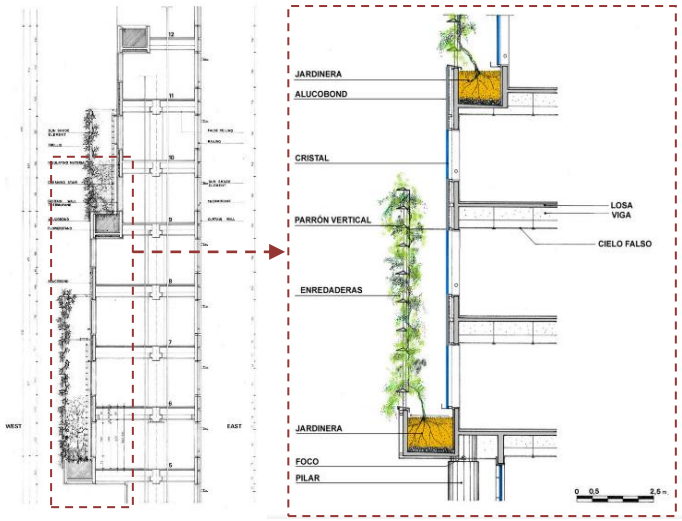

Figure 5: Section Shows the GW location and installation. [10]

Also to reduce the Urban Heat Island (UHI) effect the building has a fountain at the ground level with area 2920 m2 (Fig. 6). [7]

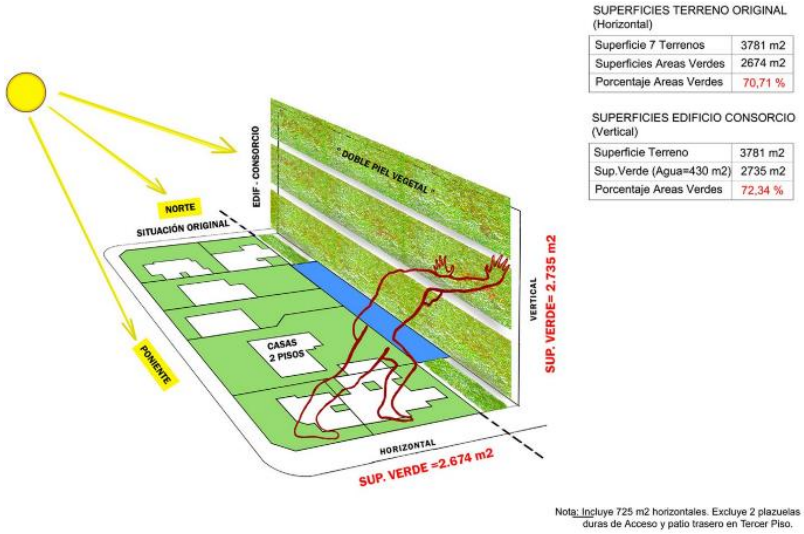

Figure 6: Pre-existing green areas VS Green Wall area. [11]

The purpose of green wall installation is as the following: [7]

1- Reduce the heat gain inside the offices by blocking the direct radiation as it reduces the solar radiation by 60%. [12]

2- Reduce the energy consumption in the building as it reduced the consumption by 48.4% which reduce the overall cost by 27.77%.

3- Increase the building's visual impact for building occupants and neighborhood.

4- Reduce the noise that came from street to maximize the human comfort in the space.

3.2. Practical Study:

The practical study will show the effect of Green Wall installation on energy consumption during three phases

1- Initial case (without green wall installation)
2- Green wall installation without air gab (installed direct to the wall).
3- Green wall installation with 60 cm air gab (installed on a structure system fixed on the façade skin).

4. Case Study

To study the effect of vertical greening system (VGS) installation on offices building and analyze how it effect on energy consumption, heating and cooling loads.

The chosen case study will be a TAs office in typical floor with area 4.7 m2 which located in the Canadian International College (CIC), Faculty of Engineering Building, 5th Settlement, and New Cairo.

The Orientation of the room is on South west with WWR 45%. And its wall material is brick covered by painting with 25 cm thickness

4.1. DesignBuilder Simulation Program:

It used to study the thermal loads of the building in terms of ventilation, the percentage of CO2 emission and the internal air movement. It studies the raw materials inside the building, the insulation and the rates of heat and cooling reduction.It also calculates the energy consumption, so it is considered as an identification certificate for the building. The DesignBuilder program considers as the first comparison program that includes the same interface of EnergyPlus program [13].

4.2. Simulation Results:

The following table (Table 1) shows the building data that used in the simulation

Table 1. Building Data for the Simulation

Building Location	New Cairo
Building Type	Office Building
Building Data	Area: 4.7 m2 (3.80*6.00 m) WWR: 45% Window Dimension: 4.00 m width and 1.30 m height Glass Data: clear with 6m thickness
Wall Layer Before GW installation	0.05 Paint 0.025 Cement Mortar 0.25 Concrete Block 0.025 Cement Mortar 0.05 Paint
Wall Layer After GW installation (without airgap)	0.05 Paint 0.025 Cement Mortar 0.25 Concrete Block 0.025 Cement Mortar 0.05 Paint 0.05 Structure System (Stainless steel) 0.20 Plants Thickness (Hedra Helix – IVY) 0.20 Water Vapor
Wall Layer After GW installation (with air gap)	0.05 Paint 0.025 Cement Mortar 0.25 Concrete Block 0.025 Cement Mortar 0.05 Paint

	0.60 Air gap 0.05 Structure System (Stainless steel) 0.20 Plants Thickness (Hedra Helix – IVY) 0.20 Water Vapor
Plants Data (Hedra Helix – IVY) [14]	Specific Heat: 2800 J/Kg°K [15] Heat Transfer: 0.36 W/m°K Leaf Density: 533.288 gm/m3 LAI: 0.005 m2/leaf
Water Vapor Data [14]	Specific Heat: 1966 J/Kg°K Heat Transfer: 5.56 W/m°K Density: 600 gm/m3
Air gap Data [14]	Specific Heat: 1004 J/Kg°K Heat Transfer: 5.56 W/m°K Density: 1300 gm/m3
Installation Orientation	South West

The Simulation has been done three times to shows the difference between the initial case and green wall installation (without air gap and with 60cm air gap).

The results were as the following; (Fig. 7)

In the initial case: the room consumed energy by 680.547 W/hr annually, the cooling load by 243.64 w/hr and the heating load by 436.907 w/hr

In the GW installation without air gap case: the room consumed energy by 492.648 W/hr annually, the cooling load by 196.431 w/hr and the heating load by 296.217 w/hr

In the GW installation with 60 cm air gap case: the room consumed energy by 389.52 W/hr annually, the cooling load by 157.40 w/hr and the heating load by 232.12 w/hr.

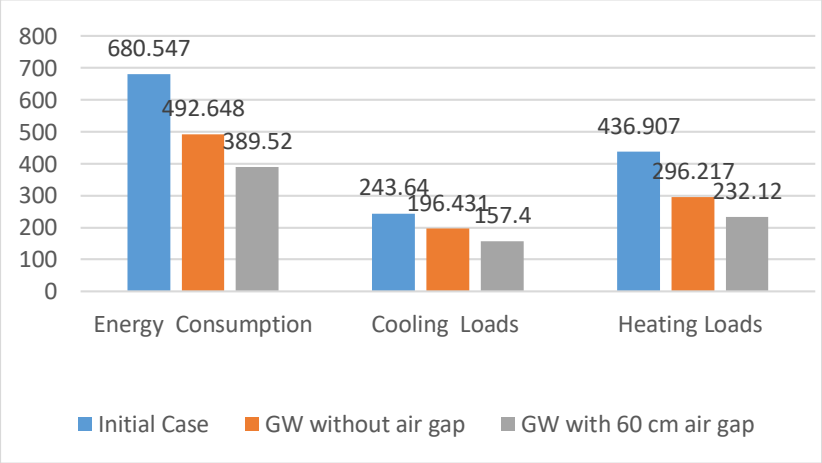

Figure 7: The simulation results for the initial case and the GW installation (with and without airgap).

And the results shows that Green Wall installation led to energy consumption reduction by 27.6%, cooling loads by 19.4% and heating loads by 32.2% in case of it installed directly to the wall without air gap (Fig. 5).

And it also shows that the energy consumption reduced by 41.4%, cooling loads by 35.4% and heating loads by 46.9% in case of it installed with 60cm air gap (Fig. 9).

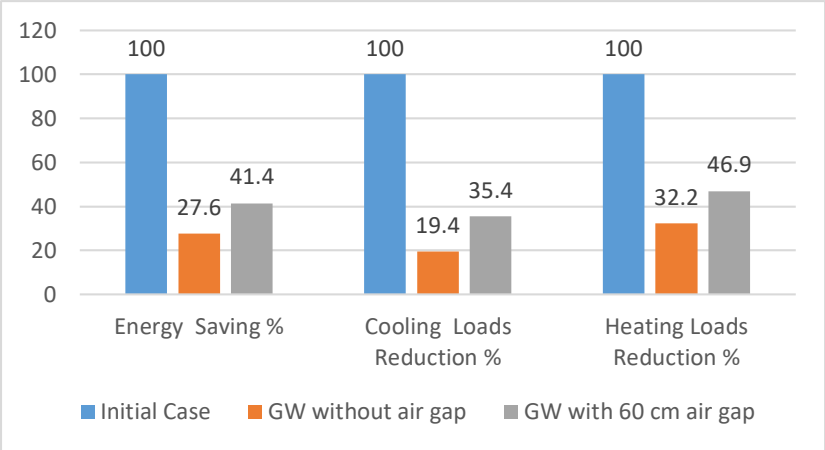

Figure 8: The Reduction percentage for GW installation (with and without air gap).

5. Conclusion

Green walls approach should be installed in a huge scale in Egypt specially in administration and public buildings as it will help the city to maximize the energy saving in addition to a lot of environmental benefits such as; air purification, water management, UHI effect reduction, greenhouse gas emission... etc. It will also reduce infrastructure costs and offers community benefits.

It could be used to compensate the shortage in the open green area and restore the ecological balance with the lowest cost as planting 1.5 m² is enough for one person to breathe for a year. Also, its benefits not only for environmental treatment but also, it could be used for food producing through using productive plants.

According to the energy problem that Egypt faced specially in the last 10 years the practical study showed how is the green wall installation minimize the energy consumption by 27.6% in case of it installed direct to the wall which led to reduce the cooling loads by 19.4% and the heating loads by 32.2%. And in case of it installed with air gab 60 cm which insure more safety for building structure the energy consumption reduced by 41.4% which led to reduce the cooling loads by 35.4% and the heating loads by 46.9%.

According to the practical study results the Green Wall Installation as a type of Green Infrastructure Techniques should be encouraged by the city to be installed widely by the owners through providing Its installation components and expertise with low cost or by granting them additional privileges from the owners of traditional buildings to ensure the idea's spread and expand its Installation, especially in administrative buildings.

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