Oana NECULAI, Irina IGNĂTESCU-MANEA, Ana-Maria TOMA, Liliana BODESCU

HYPERBOLIC SUSPENDED GREENHOUSES

Abstract: *Agriculture is one of the most important economical branches that supports and develops our society. With the increased surface allocated for the urban areas, in order to create more space for agriculture purposes, one idea is to look up. Therefore, the idea of a multi-level greenhouse in a hyperboloid structure has emerged. The hyperboloid is composed of multiple glass panels, interconnected with stainless steel rods or casings which envelope three (or more) concrete floors supported by a cylindrical concrete core. This shape was chosen for stronger structural integrity and for ensuring proper natural lighting. The main advantage for this system, besides a very low ground print, compared to the traditional greenhouses, is allowing growing different types of plants, as the soil type, water quantity, humidity and temperature conditions can be modulated for each level and sector.*

Key words: *Suspended greenhouses, smart agriculture.*

1. INTRODUCTION

Our idea started from observing the needs of today's world. Intensive agriculture is at war with the expansion of residential areas around major cities and the most of all, people and wildlife has to suffer in this war. The inhabitants of the big cities are alienated (separated) from nature and develop diseases of both physical and mental nature.

Farmers are attacking the soil and depleting it of nutrients through chemical means to control disease and pests. Thus, we as a species are constantly looking for new territories for cultivation.

A greenhouse, according to Cambridge dictionary, is a building with a roof and sides made of glass (Figure 1), used for growing plants that need warmth and protection.

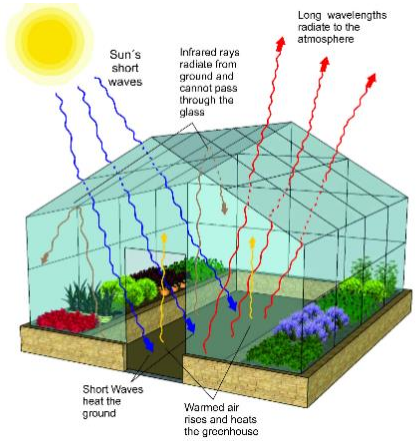

Figure 1 Typical greenhouse [1].

A greenhouse is also called a forcing structure, that is, an artificial environment in which plants are "forced" to grow, despite the harsh outside climate. So, how does a greenhouse work? The minimum requirement for any greenhouse is that it allows warmth and light to enter, providing a microcosm climate favorable to plant growth.

But How Does a Greenhouse Work? [5]

Every greenhouse operates on a simple physical principle called "the greenhouse effect". Sunlight (short waves) passes through transparent or translucent materials such as glass or plastic. When it strikes an opaque surface inside (plant leaves, greenhouse floor, planters) some of the light energy is changed into heat.

The darker the surface, the more heat is generated. The greenhouse panels are good at transmitting light, but not heat. Therefore, most of the heat stays inside.

Once the short waves hit the ground, they warm it up. Then the warmed air rises and heats up the greenhouse. Then long waves radiate to the atmosphere.

A greenhouse allows you to maintain the proper temperature and light conditions for optimal plant growth. For any greenhouse, the sun should be the primary heat and light source.

Planning for a new greenhouse is one of the most important steps a grower has to take. Proper site selection, orientation, size, glazing material and many other factors enter into the decision [2].

Greenhouses can be of different shapes and sizes, from small and regular shapes, to big, covering extended areas of land.

For example, Victoria amazonica (giant Amazon waterlilies) in a large greenhouse at the Saint Petersburg Botanical Garden, (Figure 2), [3].

Figure 2 Greenhouse No. 28 at the Saint Petersburg Botanical Garden.

Cornwall, England, on the island nation's most southwestern edge, is home to the Eden Project and the world's largest greenhouse. This amazing collection of bubble-style biodomes house a collection of plants from across the world, from the rain forests to the Mediterranean to the rolling hills of England herself. From an architectural standpoint, these sustainable greenhouses are massive, powered in part by wind energy and fed in part by rainwater collection systems. Inside, the flora of the world thrive year-round, where spectators are welcomed to walk the misty paths amidst exotic plant life. The juxtaposition between the lush climate inside and the cool countryside of Cornwall is quite breathtaking, giving visitors a true escape into beautiful foreign worlds (Figure 3) [4].

Figure 3 Bubble-style biodomes [4].

We came up with the idea to look up and create spaces in space for both agriculture and humans and to allow nature to follow its normal course for the good of the entire planet Earth.

2. HYPERBOLIC SUSPENDED GREENHOUSE

2.1 The structure

The proposed hyperboloid structure is composed of multiple glass panels, interconnected with stainless steel rods or casings which envelope three concrete floors supported by a cylindrical concrete core (Figure 4).

The rigid core had a hollow middle, which goes down to the groundwater layer, where a pump brings water to all of the floors, therefore reducing the costs of irrigations. At the top, the glass structure is slanted inwards so that rain and snow to slide into the well, thus collecting it for irrigation purposes. The shape was chosen in order to have a stronger structural integrity.

The platforms which compose the elevated floors are suspended as cantilevers fixed on the concrete core, and the concrete wall presents holes placed 90 cm over the level of the platform, where the hoses with the pumped water are placed.

Access to the higher floors of the greenhouse is made by either a simple iron stepladder with a pulley system that eases the transport of fertilizers and gardening tools, or a spiral staircase around the concrete core (Figure 5).

Another possibility to access the upper floors is with the help of a platform / elevator that slides along the straight vertical stairs that can be used in emergency situations as a fire escape.

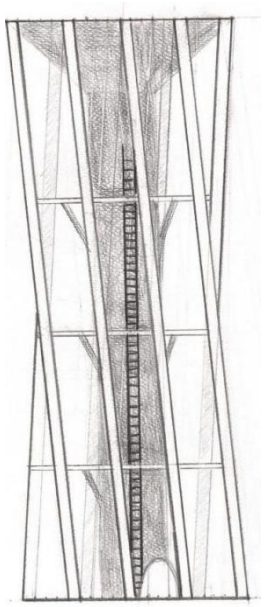

Figure 4 Hyperboloid structure, the stairs and the fountain in the middle, the trunk of the cone at the top.

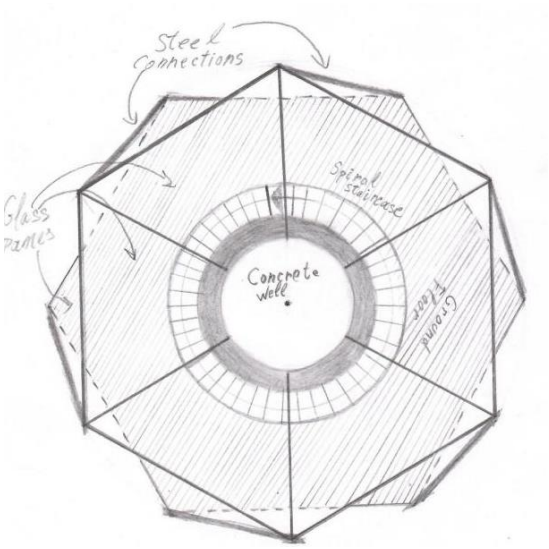

Figure 5 Section with a horizontal plane.
Spiral staircase around the concrete core for access (one of the options).

2.2 Greenhouse incorporated systems

The central pillar of the structure can be constructed to act also like a water tank. The water source is the underground groundwater but also the rainwater and the precipitation in the form of snow. In this fountain is located a pump that serves the systems installed at each level. Sensors are mounted on each preset area that measure soil moisture and temperature and require the central unit to supply water at a certain temperature when necessary. The pump starts automatically and pushes the preheated water through the piping system to the area that launched the command.

Similarly, the sensors that measure humidity and air temperature launch the command to the central unit and through the existing nozzles in the ceilings water is

sprayed in the required amount and at the preset temperature. Ensuring heating in winter or cooling in summer is done by ground-to-water heat pumps with deep drilling.

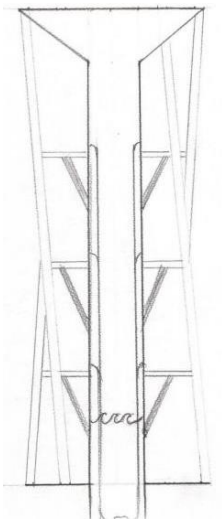

Figure 6 Section with a vertical plane.
The fountain and the water level, the trunk of the cone that collects rainwater for a water supply.

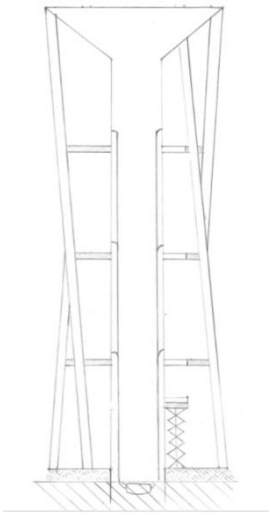

Figure 7 Section with a vertical plane.
Fountain and pump, the system of pipes for irrigation and for the supply of air humidity.

At the top, inside the trunk of the cone, there are solar panels mounted for capturing the solar energy and converting it into electricity and heat. These panels allow the energy independence of the greenhouse.

Photovoltaic solar panels will power the irrigation pump, elevator, temperature and humidity sensors, light intensity sensors, ambient, technical and safety lighting.

The solar thermal panels will heat the water for irrigation, which leads to the efficiency of maintaining a constant temperature in the greenhouse. At the same time, irrigation with water at a controlled temperature is beneficial for the plants.

This water will also serve the toilet located on the ground floor of the building.

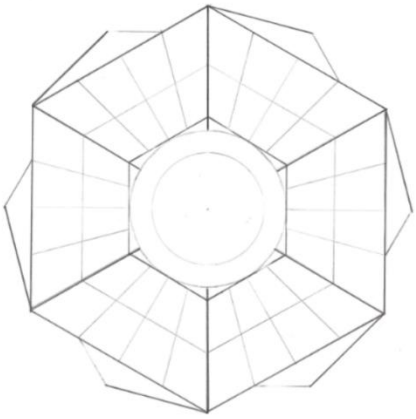

Figure 8 Top view.
Photovoltaic solar panels and thermal solar panels which are placed on the cone trunk.

Depending on the obtained energy level, the efficiency of the solar panels, the floors have the possibility to rotate according to the parameters of the season, day, hour, intensity of sunlight so that all the plants benefit from optimal development conditions.

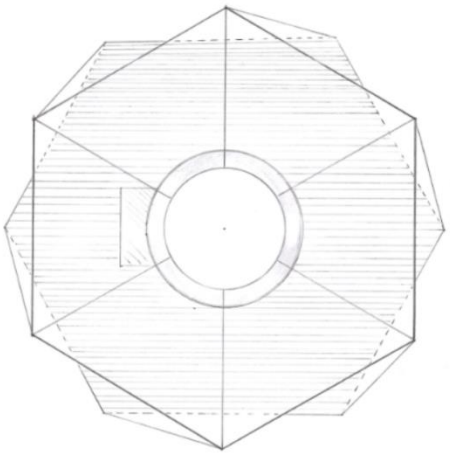

Figure 9 Section with a horizontal plane.
There is the possibility to rotate a level depending on certain default settings.

2.3 Advantages

We can enumerate a sum of advantages such as reduction of the used space (footprint on the ground).

Therefore, it is easier to handle materials due to the short distance in which they are physically carried.

Each level and sector have controlled humidity, temperature, the amount of water in irrigation, for a wide variety of cultivated plants and for an increased comfort of the users of the respective space.

Another advantage is that the structure is compact and a valuable architectural impact on the area in which it is located.

The built-in systems (photovoltaic solar panels, solar thermal panels, fountain and rainwater collection system) ensure that it is a self-sufficient structure, without minimal external energy consumption which allows it to be build in different environments and places.

Possibility of extending the height with several levels so that at each level events or activities take place simultaneously to ensure an increased economic efficiency of the building.

3. CONCLUSIONS

These greenhouses can have a wide applicability in urban areas due to the very small occupied area and due to the fact that they are autonomous from all points of view.

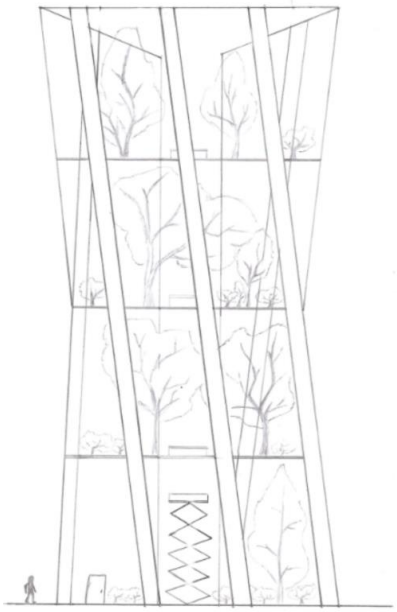

Figure 10 Front view.
There is the possibility of using each level simultaneously, for various purposes.

Greenhouses can be used successfully as offices, conference rooms, medical offices and therapeutic spaces with very low utility costs and also have a significant benefit on the well-being of the user. Considering the multitude of areas that can be delimited, it is possible to create appropriate spaces for chromotherapy, aromatherapy, melotherapy or psychotherapy in the middle of nature and also in the middle of the city.

They can be used as teaching spaces for pupils and students from schools and faculties with a profile in agriculture, horticulture, animal husbandry, biology, chemistry, geography, geology, environmental protection, arts, psychology, philosophy but also for those who will become specialists in the fields of construction, installations, electronics, electrical engineering, hydrotechnics, mechanics.

In terms of agriculture, this idea can be extended to exotic plants, environmentally demanding plants or "clean crops" near cities so that delivery times to the final consumer are greatly reduced. Also, this kind of greenhouse makes people's work much easier because the horizontal distances are reduced and the vertical one uses the elevator.

REFERENCES

[1] *https://dictionary.cambridge.org/dictionary/english/greenhouse*
Accessed: 2022.03.12.
[2] *https://www.greenhousemag.com/article/greenhouse-0711-style-tech-solutions/*
Accessed: 2022.03.12.
[3] *https://en.wikipedia.org/wiki/Saint_Petersburg_Botanical_Garden#/media/File:Botanical_Garden_V.L._Komarov_Botanical_Institute.jpg*
Accessed: 2022.03.10.
[4] *https://www.thecoolist.com/eden-project-the-worlds-largest-greenhouse/*
Accessed: 2022.03.10.
[5] *https://www.backyardgardenlover.com/how-does-a-greenhouse-work/*
Accessed: 2022.03.10.

Authors:

Senior Lecturer Oana NECULAI, Gheorghe Asachi Technical University of Iasi, Department of Civil and Industrial Engineering
E-mail: oana.neculai@academic.tuiasi.ro
Assistant professor Irina IGNĂTESCU-MANEA, Gheorghe Asachi Technaical University of Iasi, Department of Engineerting Graphics
E-mail: irina.ignatescu-manea@academic.tuiasi.ro
Senior Lecturer Ana – Maria TOMA, Gheorghe Asachi Technical University of Iasi, Department of Engineering Graphics
E-mail: ana-maria.toma@academic.tuiasi.ro
Student Liliana BODESCU, George Enescu National University of Arts, E-mail: l.bodescu@yahoo.com