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XI МЕЖДУНАРОДНА НАУЧНА КОНФЕРЕНЦИЯ
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ECOLOGICALLY PROACTIVE STRUCTURE CONSTRUCT – LEPENSKI VIR MUSEUM SERBIA

Adrijana Savić [1], Ninoslav Cakić [2], Iva Despotović[3]

ABSTRACT:

Following the request of the museum Lepenski Vir, Serbia to generate a solution for the extreme overheating air masses process during temperature seasons, this project design focus is to use biophilic and environmentally proactive methods in design and construction to achieve systematic long-term change in heating and cooling processes of the museum greenhouse structure. By combining proactive ecological design with advanced architectural construction technologies, a mimicry of natural atmospheric elements lowering extreme differences of temperatures is achieved, which processes neutralize biochemical products of industrial elements of the structure conducted by sun ray exposure/ UV radiation. An environmentally proactive method relies on mimicry of humid vs. non-humid biospheres constructs, dispositioned at strategic heights of the existing structure. By implementing a large-scale greenhouse structure to preserve museum conditions, a biosphere design becomes a permanent museum installation evoking the natural habitat of the Lepenski Vir culture primarily, while secondarily, a biochemical construct of atmospheric ecosystems produces an independent gaseous membrane initiated by plants clusters. A 7 - 15° C neutralization is achieved, winter through summer conditions. Three thousand plants as part of the newly added construct biospheres, absorb CO_2, formaldehyde as well as hydro-carbonated emissions, combined with waste matter collector, together they form one of the most environmentally proactive LEED museums.

Keywords: environment, cooling, and heating method, greenhouse structure

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1. Introduction

Lepenski Vir archaeological site/museum is a heritage of unprecedented value for The Republic of Serbia, Europe, and the entire world. The architectural museum project transcends a conceptual language that adequately exhibits historical artifacts of the Lepenski Vir culture, by evoking an experience of the historical processes of the LV culture and its natural habitat. The existing architectural space through its structure design, material values, and exhibit path schemes allow users to comprehend all key elements of the culture throughout various vantage points of the museum, synchronizing a representation of artifacts as well as environmental elements of the processes in nature respectively. Its light values and vantage points represent a solid ground for further concepts, as upcoming contemporary museum tendencies in user experience evolve in needs and imagination.

The next phase conceptually for the museum is to further evoke conditions of natural elements in the space itself, especially because, pioneer green architecture and construction practice was implemented by the culture six thousand years ago, directly following local natural resources: Danube, humidity, and bio isolators as construction materials.

Structurally, being built as a cascaded greenhouse as shown in Figure 1, thermodynamic processes of the museum create an extreme effect of a greenhouse air nonreactive gaseous monolith. As a result of non-existing organic layers in a greenhouse set up, the structure and its standardized operational codes leave us with a monolithic central airmass, covering 90% of the interior atmosphere, which as such, behaves immune to occurring effects of the HVAC system existing today. Currently installed high standard HVAC system is ineffective in countering overheating processes in extreme temperature conditions, therefore, an organic and environmentally proactive design offers an ecological solution for the currently nonreactive thermodynamic processes – neutralizing and redirecting bi-products to a proactive process for its micro and macro environment.

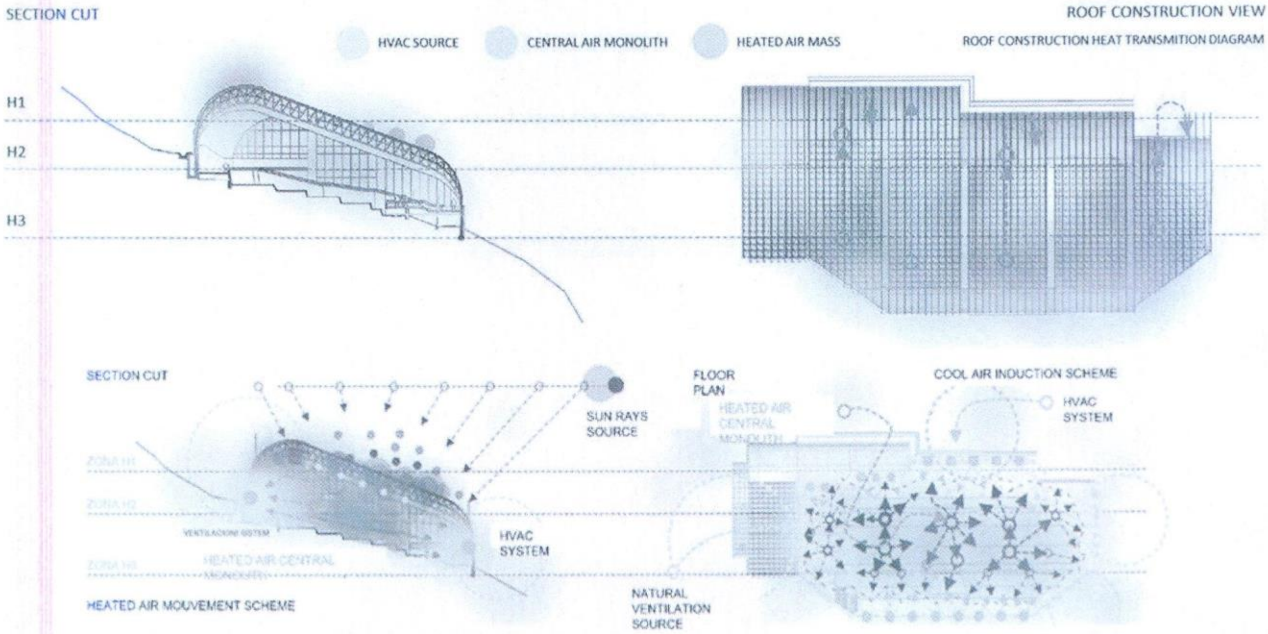

Fig. 1. Existing Conditions Structural Analysis Diagram

A cascaded greenhouse structure, with a steel construction framework, and carbonated semi-translucent panels, without an organic layer in the interior, produces a temperature increase of 10-15°C during summer heat periods. Central monolithic air mass occupies 90% of the structure coherently, as its humidity value remains solid and still, producing a vertical airmass wall barrier for the upcoming HVAC ventilation cool air mass. Figures 1 and 2 visually explain existing conditions and processes that remain unsolved through existing conventional technology.

The goal of our construct is to use inventive construction techniques to provide a structural element that uses smart planning of organic biospheres/ live plant systems to adhere to the physical negative impacts of the existing structural and thermodynamic values. Designing and building our construct achieved mimicry of organic ecosystems indoors as part of inventive architectural and construction practice.

Lepenski Vir museum is determined as a greenhouse. However, a museum considered a greenhouse structure becomes a very specific operating system whose parameters determine air movements, humidity, and coverage of organic layer areas compliant with standard museum regulations determined by the Ministry of Culture of the Republic of Serbia. Considering these guidelines and regulations, to bring this non-vegetational greenhouse to a museum-coded organic greenhouse, it was requested to create constructs of organic biospheres in a range of 10-15% of the floorplan use. These plant-based biosphere constructs, dispersed through several layers of different positions in height instances, would also need to stimulate humidity polarization, which furthermore would stimulate currently nonexistent internal air mass flow. The following brings us to the core research conditions and values:

- Biosphere of plants with values of low maintenance plant species tested as humid/nonhumid house plants which absorb toxic emissions, produce, and stimulate heat exchange and react positively towards temperature changes of the outside conditions.

- Structural additions to reinforce the bearing biosphere layer structures, its operational morphological needs, and safety regulations.

A study done by NASA "Interior Landscape Plants for Indoor Air Pollution Abatement" [1] represents laboratory-tested effects of plant processes in creating project desired conditions, affecting formaldehyde, benzene, and ethylene as interior byproducts due to various thermodynamical processes. This study directly transcends proven methods on how to use morphological processes of species to address thermodynamical values at the LV Structure – through product emissions and humidity indexes.

According to the Nasa study [1], low-light-requiring houseplants, along with activated carbon plant filters, have demonstrated the potential for improving indoor air quality by removing trace organic pollutants from the air in energy-efficient buildings. This plant system is one of the most promising means of alleviating the sick building syndrome associated with many new, energy-efficient buildings. The plant root-soil zone appears to be the most effective area for removing volatile organic chemicals. Therefore, maximizing air exposure to the plant root-soil area should be considered when placing plants in buildings for best air filtration. This study reinforces the project scope intention to enable up to 1500 m^2 of soil exposure of the LV proactive installation, which is targeted to absorb all the above chemicals emitted from the structure- through both freestanding and air installations. Further results of this study determine a list of multifunctional plants which form targeted organic biospheres.

2. Methodology

Ecologically proactive design solutions in built environments as a method have a purpose to, through architectural and construction design techniques in construction materialization and space planning, offer biophilic method solutions to the tasks required in micro and macro settings. This principle in combining organic and non-organic values in built environments implies creating biologically live constructs that mimicry nature in its essence. This is achieved by simulating natural processes in captivated spaces ensuring their life cycles as circular sustainability.

Applying environmentally proactive methods to the extreme greenhouse effect at the museum of Lepenski Vir through its construction update, we generated a scope of design effects needed to implement the solution through sustainable organic biospheres in compliance with general museum criteria and regulations, which offer to directly merge industrial processes behind architectural and construction practices with proactive design– a leap forward towards nonabrasive structures in terms of user and environmental effects.

When multidisciplinary research was performed consisting of technical and static conditions of the existing structure, thermodynamic processes of structural and gaseous entities, a proactive setup of biosphere construct was determined to be dispersed throughout the structure in several height instances to create sustainable processes adaptive to seasons and organic life cycles, ensuring optimal costs and user/ occupant safety.

Our team used contemporary computed generated data to determine structural statical values using Robot Framework, air, and hydro mass flow analysis through Autodesk CFD as start and result values, as well as reliable botanical constructs and data to monitor long-term adaptive processes of plants clusters' lifecycles. The method is presented through Schematic Design phases as shown in Figure 2.

The goal of this installation is to use a merge of construction and environmentally proactive design to affect temperature change within the structure of the museum. Respectively, biosphere installations are to regulate temperature changes primarily, while secondarily being a museum installation as well as a pollution control system.

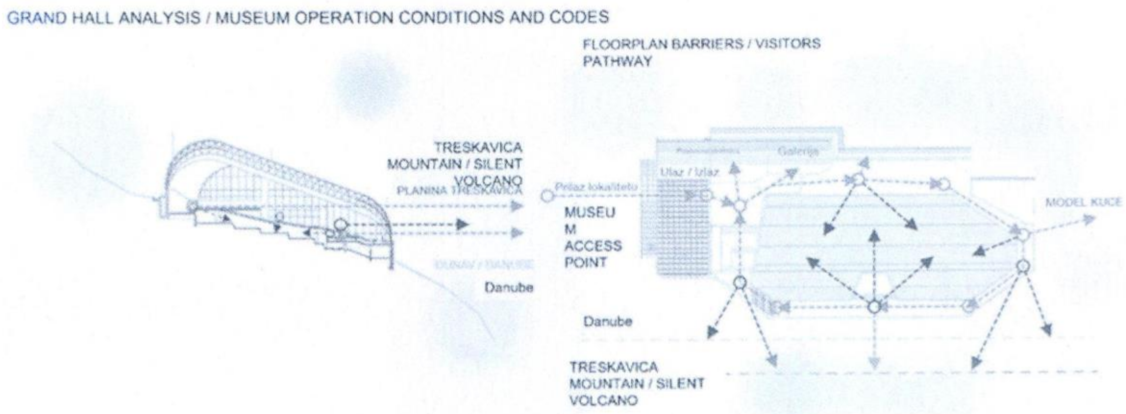

Fig. 2. Museum operations diagram / Exhibit schemes

To start design planning of the upgrade, museum conditions mandated by Ministry of Culture codes need to be beforehand structured. Figure 2 diagram states floor plan areas that must remain uncompromised in various heights, considering material and air conditions. Vantage points must remain uncompromised by the newly added construct, as the relationship between artifacts and environmental parameters (Danube / Treskavica mountain) need to remain constantly visible. The locality itself widely needs to remain protected from the construct's effects at all heights.

After careful consideration of the pre-existing conditions, and environmentally proactive construct is allocated to address drastic temperature changes, following biochemical reactions of the existing structure.

The environmentally proactive structure is a multifunctional construct is consisted of (Figure 3):

- MEMBRANE - Outer Construction Upgrade – roll/ collapsible roof-shade system
- ECOSPHERE - Interior multifunctional construct – a multi-height construction of organic and non-organic biospheres added as suspended and free-standing units.

Outer construction upgrade - is an essential construction design approach in neutralizing extreme interior atmospheric conditions. As per the data collected from the museum records, a 15° C additional temperature value is added during heat season, as the construction itself behaves as a heat-transmitting object continuously throughout a 24hrs period.

Experimental projects in the past decades have shown that a translucent net added to the outer structures can significantly decrease the capacity of heat transcended through sun rays, which to a steel core structure of the museum, its carbonated skin paneling, is a logical design method to apply thermodynamically and translucency wise.

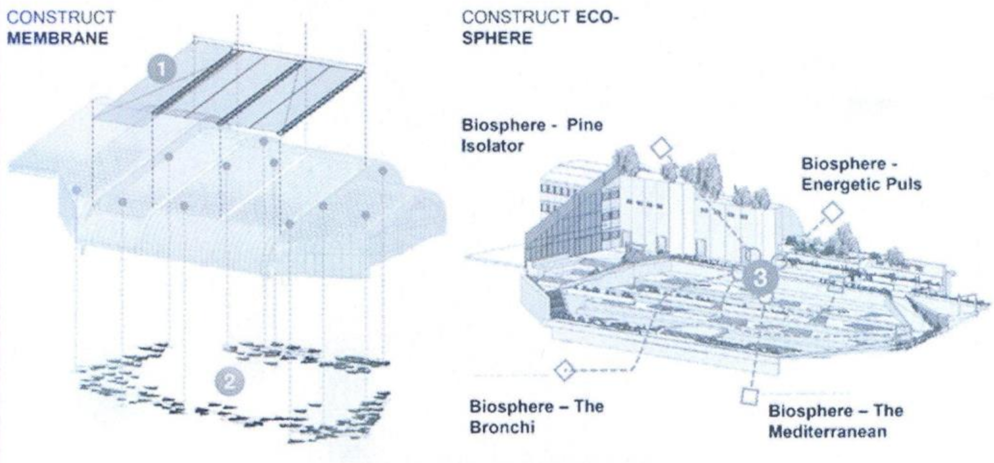

Fig. 3. Construct Diagram: Area 1 -Outer Construction Upgrade Roll, Area 2 Collapsible roof-shade system, Area 3 Interior multifunctional construct

Therefore, an aluminum suspended shade structure is intended to be added on top of the existing roof structure. This system is to be activated electronically once the outside temperature reaches 30°C. Shades themselves are designed as a net structure with thread density designed to let enough light source value as determined by the original project parameters secondarily, while primer criteria in thickness and positioning are to block sun rays heat capacity to the surface below to reach best results throughout seasons.

After computer-aided design projections, when 70% of the roof structure is covered by the added outer construct, we prevented the interior temperature fluctuations in a range of 7-10° C.

Interior Multifunctional construct – becomes a construction entity that uses multiple approaches of an isolated greenhouse setup. A combination of suspended and freestanding plant pots allows us to push the boundaries of manmade artificial constructs, by applying to them an outer layer that becomes an alive micro-ecosystem – an environmentally proactive unit that enhances submersion of artificial with organic natural, achieving multiple environmental effects in their thermodynamical processes.

Designed as Biospheres, hanging and freestanding, their materialization and morphological functions address and create a greenhouse set up in the museum, evoking the Mediterranean culture of Lepenski Vir, while primarily they served as a smart ecosystem which absorbed CO_2 values, absorbed byproducts of artificial materials and more importantly, they formed polarized atmosphere which prevented cooling and heating respectively where and when necessary.

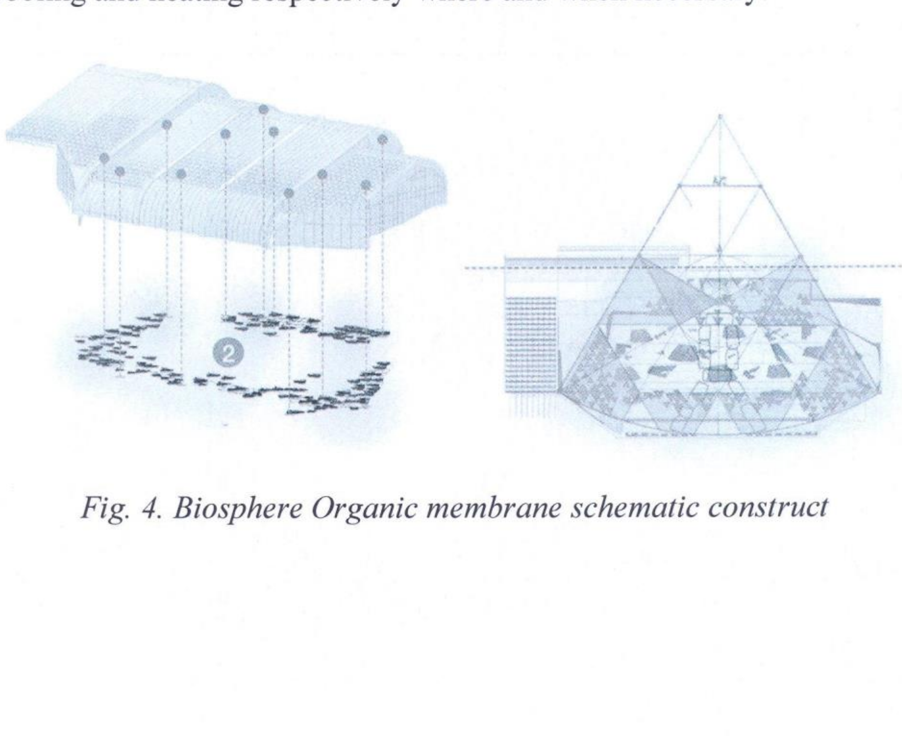

Fig. 4. Biosphere Organic membrane schematic construct

Humidity as an atmospheric value was taken from the heritage of Lepenski Vir's cultural habits. Humidity guided this culture to settle near the Danube to protect from heat and cold fluctuations in seasons, as well as to provide an isolator for their organic homes. The research shows that this culture used organic materials, to be more precise fern leaves, as a roof isolator, becoming a pioneer human in green architecture 6000 years ago. In so it is crucial to have this atmospheric value to adhere to temperature changes, a mimicry of humidity values generated by water and plant formations becomes a construction design construct, as well as an ecological installation that is alive in a museum as an exhibit culturally. This construct is a suspended addition to the existing structure. Structurally, designed based on the triangular matrix used by the LV culture, it consists of an aluminum frame at its triangular boundaries, which furthermore supports the core structure waterproof "grow bag" surface to become a habitat of moisture plant sphere to grow on. A hydraulic suspension mechanism is installed for each of the constructs to allow mobility and safety measures throughout the maintenance procedures long term. Figures 3 and 4 display the area occupied by this vital interior layer. Thermodynamically, as proven in the study by Susan P. John and Karl H. Hasenstein [2-4], humidity driven biosphere of ferns, uses its humidity to prevent heat influx from the outside to reach lover levels of the interior, preventing the overall temperature change from 5-10 degrees during the summer period, while additionally preventing heat loss during the winter up to 5°C providing a revolutionary achievement as an adaptable construction method for micro and macro-built environments. Of all the conceptual constructs, this layer has the utmost significance for construction innovation, as its stability, smart irrigation systems, plant resilience, and controlled interactive behavior proved that organic and non-organic constructs became an environmentally proactive element of architectural and construction practice in micro and macro scales.

Once the main source of temperature change is neutralized, the rest of the museum space upgrade is a construct that should support values of keeping the air masses cooler during summer periods, or warmer, during winter periods. Thermodynamically, air masses of different humidity values, as well as temperature values will create airmass fluctuation. Therefore, strategically placed free-standing structures will form a biosphere that produces various levels of humidity, temperature emissions, air pollution filtering properties, and bio exhibit museum properties.

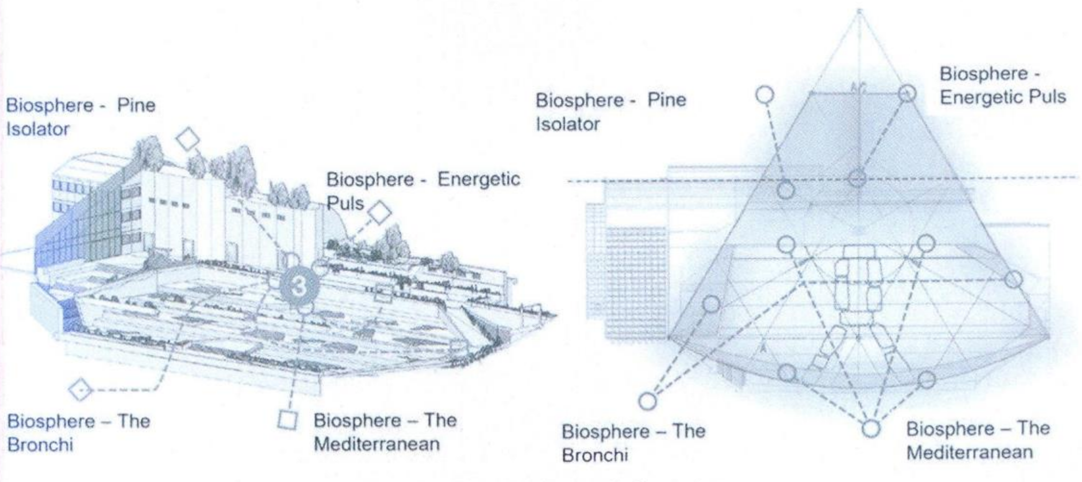

Fig. 5. Eco-Sphere Schematics

A sequenced design of freestanding structures, such are pine roof planters, admissions pavilions, promenade planters are constructs [5] that provide additional microclimates for various museum activities and functions [6-8]. Pine installation construct reduces the heat geared [9-10] and transmitted from the office structure of the museum, while the admissions desk structure further reinforces cooler temperatures for the museum employees welcoming and guiding visitors.

Ensuring that employees live in temperature optimate conditions is one of the primary goals of the project results.

3. Results and Discussion

Collected data through our multidisciplinary design projected research showed, that a $3660m^2$ of greenhouse structure requires up to $1500m^2$ of biosphere organic systems installed to neutralize the entire toxic inducted gaseous emissions, stabilizing 7- 15°C in extreme temperature shifts throughout seasons extreme temperature values as shown in Figure 6.

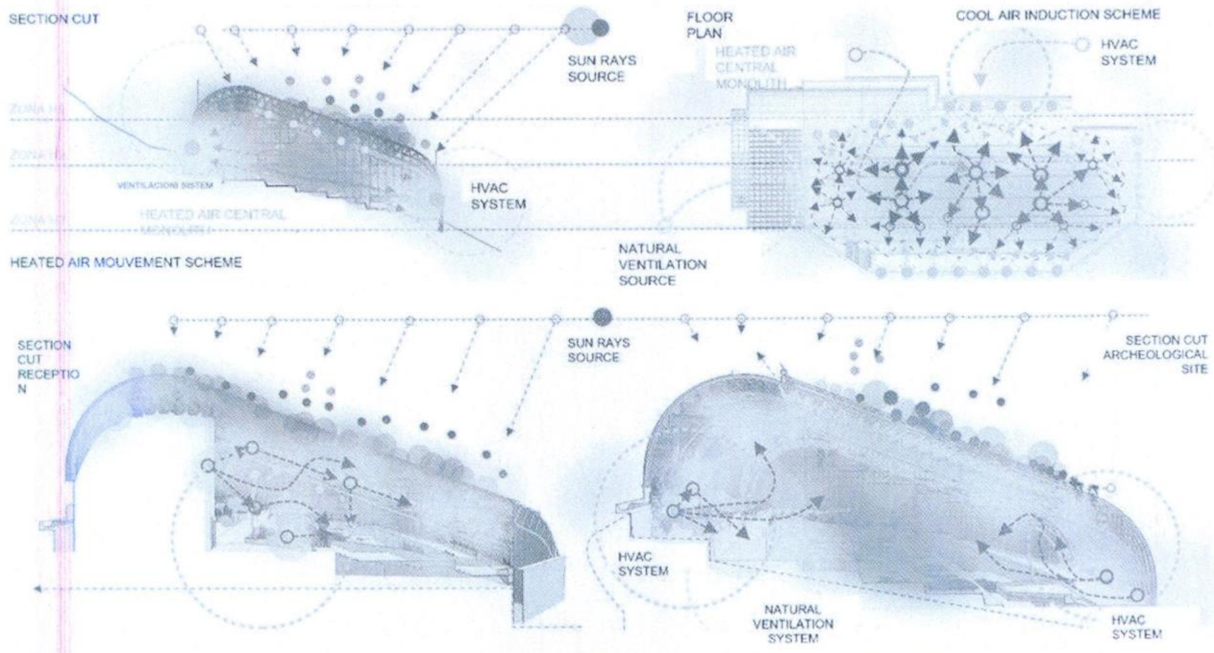

Fig. 6. Start vs Result Thermodynamic Airmass values diagram

A direct result of the architectural and construction smart planning procedure is a remote-controlled rollable fabric shade was added to the exterior of the structure. This became a prerequisite of the project scope, as research proved its design reduced overheating of the structure starting from 70% externally, preventing the overheating problem from the outside before it impacted interior values. Using this new innovative method, the ambient temperature is decreased, which increased the efficiency of air conditioners in the building. The roof temperature is reduced reducing energy usage.

4. Conclusions

Interior constructs innovation, through suspension ecosystems and biospheres and suspended irrigation systems were brought up to exhibit museum codes and regulations. Additionally, a completed design concept was revitalized to become a truly “alive” construct - culturally, structurally, energetically, and financially. Here hard matter and gaseous entities using smart planning and natural responses became an example of why and how environmentally proactive architecture and construction apply to, equally both, the NEW and the OLD, projects and structures. When we systematically through technology support natural elements, we prove to achieve truly sustainable solutions from which we can multi-functionally affect micro and macro environments around us and for us.

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