

Engineering Department.

ISSN: 3067-2457

Lessons in Enhancing Human Performance from The Inspired Architecture of Casa Oleaje Tulum

Nathan Klarer^{1*}, Jose Javier Damian Esteva² and Natalia Mujica Leon²

¹Grey Ghost Strategies, Engineering Department.

²Grey Ghost Strategies, LLC.

Received: 🗰 2025 Mar 19

Accepted: 🗰 2025 Mar 25

Published: 🗰 2025 Apr 28

Abstract

Situated in the tropical rain forests of the Riviera Maya, bounded to the south by the biodiverse Sian Ka'an preserve, our team embarked on the design of Casa Oleaje using principles from the fields of bioengineering and architecture. During the design process, we incorporated engineering techniques to create a holistic environment which encourages recovery and neurological flow states. Additionally, the timeless architectural style creates a space to separate the occupant from the currents of modernity. We believe the lessons learned during the design can be adopted by other buildings to achieve the same benefits.

keywords: Casa Oleaje, Architecture, Solar, Chimney

1. Introduction

The introduction of bio design principles to architecture has been the subject of formal interest by architects for decades. Our project, Casa Oleaje, aims to advance current research through its distinctive fusion of architectural and bioengineering elements. During our design process for the Casa Oleaje project in Tulum, Mexico we decided to incorporate biologically inspired, Mesoamerican, and Classical architecture styles. Then, we took an engineering approach to factors such as household temperature, solar gain, and acoustics to intentionally create an environment that encourages recovery and neurological flow states. This combination of architecture and engineering resulted in a unique structure that taught us lessons which can be adapted to future construction.

This paper will explore each relevant research area used to develop the villa. We will discuss the decisions made in each area and their implications on various factors such as aesthetics, living quality, and measurable metrics including; acoustics, solar gain, temperature, and lighting. Finally, we will summarize how each component piece forms a system which encourages the production of beneficial neurological states and enhanced human recovery. The results of this paper can be adopted by new architecture projects which seek to achieve the same behaviors emphasized in our design.

Corresponding Author: Nathan Klarer, Grey Ghost Strategies

2. Methodology

2.1 Regulation of Ambient Temperature

The Riviera Maya is a hot and wet climate with temperatures that average between 80 and 90 degrees. Therefore, regulation of temperature within the building was high priority. This was accomplished through the reduction of solar gain by specifying the orientation of the building's walls, the inclusion of a solar chimney in the design, and directing airflow over the water of the pool. These aspects will be discussed in the subsections below.

2.2 Minimization of Building's Solar Gain

The walls of the building are oriented towards the northeast and south-west at a 52-degree angle. Given the pattern of the rising and setting of the sun, we expect the wall facing south-west to be exposed to approximately 3 hours of direct sunlight per day. This contrast with an alternative orientation on the north-east axis where walls of the same size would experience 6 hours of solar gain per day. The total area of the south-west walls is 70m2. Near our location at the equator, a given structure will average



Figure 1: The Solar Chimney Included in the Design Encourages Hot Air to Travel up and Out of the Home

200 W/m2 of power from direct sunlight. Hence, our engineered 50 percent reduction of accrued solar energy is equivalent to 2,160 kJ per m2 of reduction per day. Assuming that the building has a specific heat constant close to that of concrete, or .96 kJ/kG, and a reduction of 2,160 kJ, we estimate that this will reduce temperatures by 1.69 degrees per square meter of wall [1]. Hence, the wall orientation provides a cooler living experience for the residents of the building.

2.3 Inclusion of Solar Chimney Stairwell

The function of a solar chimney can be succinctly described in the following sentences. Sunlight hits the exposed tower structure and heats the air inside the chimney. The sunlight creates a heat gradient that encourages the hot air to exit through the top of the structure and sucks colder air into the solar chimney. This natural, continuous, process creates a ventilation system that encourages the flow of colder air through the living spaces of the structure. In total, our solar chimney is 9.80 m tall with a volume of 77 m3 which provides a large body of air for circulation.

2.4 Positioning of Water in Major Airways

The winds in the Yucatan flow from the Caribbean over the

lush jungle of the peninsula. Cardinally, the Caribbean wind originates in the East and the Southeast where it journeys through peninsula to the West and North. Hence, Casa Oleaje is positioned along a southeast axis of 52 degrees that allows wind to flow through the back of the home and out the front of the home. Conveniently for our design, the winds in the Riviera Maya flow in the same direction throughout the year thus reducing the project's complexity [2]. Therefore, we positioned the pool directly in the center of the home, thereby, cooling the air over the pool as the wind flows from the southeast. The effect acts in concert with the solar chimney to keep the ambient temperature low.

2.5 Acoustic Noise Reduction

The scientific literature has established numerous negative effects from noisy environments, including but not limited to, worsened cardiovascular health, poor mental health, and damage to the nervous system [3]. Thus, we endeavoured to use various acoustic techniques to improve the peace and tranquility of the home. The intent was to create a space that shields occupants from disruptive noise thereby enhancing their privacy.



ESQUEMA DE LA FACHADA POSTERIOR

Figure 2: Shown Above are the Exterior Facade Proportions

2.6 Ceiling Height

The ceilings in the main residential building were set to a height of 3.06 m (10 ft). It is understood that the potency of sound waves is reduced by a factor of a square for every

doubling of distance from the source. This is due to wave diffusion during the journey, also described as an elongation of the waves, which results in a reduction of potency. As a general rule of thumb, the potency of a sound wave reduces

Journal of Advances in Civil and Mechanical Engineering

by 6 db every time distance doubles after traveling 1 m from the source. Therefore, we estimate that our design creates a 6 db reduction on the exit journey and a greater than 6db reduction on the return journey. This calculation is performed by taking the following travel segments; the first segment spans 2 meters to the ceiling after the initial 1-meter trip from the source, and the second segment returns 3 meters to the source. [4].

2.7 Acoustical Clouds

The interior design will boast acoustical clouds constructed from natural materials found in Tulum. Natural materials of the region allow us to incorporate an organicist artistic perspective into the interior design. Acoustical clouds break sound waves as they travel through a space. Once the sound wave is broken, it is dampened, and no longer as potent [5].

2.8 Sensory Enhancement Architectural Patterns

Neurological Flow states can be induced through the development of positive conscious awareness to beauty within design [6]. Originally noted in philosophical texts like those above, scientific studies have further confirmed the effects of beauty by measuring brain patterns during the observation of beautiful objects [7]. During our design process, we capitalized on the scientific research and the theory of beauty to craft a stimulating sensory environment.

2.9 Cubic Mesoamerican Rear Design

The rear of the home exhibits a cubic pattern inspired from Mesoamerican architecture with the intent to invoke an aesthetic response. To allow the homeowner to interact with the Mesoamerican Cubist design directly, each level of the home boasts an exterior botanical terrace for viewing [8]. This ensures that the Cubist design is simultaneously functional and beautiful. The balance between solid and void creates a harmonious aesthetic, imparting a sense of solidity, security, and character.

The rear facade receives more sun rays during the day than any other face of the residence since it is facing south. On this rear facade, a ratio of no more than 50% between windows and walls was used, ensuring that heat gain is minimal during the day and giving an appearance of heavy volume to the entire facade. The result is a great comfort in the inner space of the bedrooms while emulating ancient construction.

2.10 Repeating Alternation of Stairwell

The stairwell of the home exhibits an alternating pattern designed to orient the viewer's gaze up from the pool garden. The pattern capitalizes on a kaleidoscope effect that creates a mesmerizing and pleasing visual pattern. The lattice modulation is divided into 5 parts, the three central modules are made up of hollow clay blocks and the two modules at the ends are different. The lower module is left empty to achieve air circulation and wooden sticks are inserted into the upper module to give the sensation of lightness. The staircase rises a height of 3.30m on each level with steps that are 1m wide, with treads of 30cm and rises of 17.6cm in height, a very comfortable ratio for use. The circulation on the stairs

is comfortable because it is divided into different sections, and the longest part has 8 consecutive steps before reaching a landing. This makes it less tiring to climb. Additionally, while moving through the interior of the staircase, one can see outside through the lattice, distracting the user from the monotony of climbing it.

2.11 Placement of Columns to Orient Gaze of Viewer

The columns and balconies in the patio serve two purposes: first, to create a visual focal point from the main entrance through the salon and onto the pool. This reorients the viewer to conceil the large latticework that surrounds the staircase for later discovery. The second objective is to allow proportion and harmony at the human scale because we have a three level facade in a narrow space. This combination, beyond expressing the use of classic architectural elements, helps lighten the composition of the entire patio.

2.12 Multi-Level Open Air Design

The home exhibits a multi-level open air design pattern intended to maximize the advantage of the home's Tulum Beach location. Scientific literature has shown a significant number of benefits to human physiology from exposure to nature. There are three open areas in the home starting from the pool garden on the lower level. The entrance salon rooftop exhibits another. And, finally, the master bedroom has a private open air terrace. The open spaces in the design encourage homeowners to embrace the climate and engage directly with nature.

The total usable open-air area of the home is 157m2, distributed as follows:

- Pool, 14m2
- Gardens, 107m2
- Roof garden, 20m2
- Master bedroom terrace, 16m2

The distribution of this spaces is important because the occupant can reach every one of them without entering the private area of the house. This is important because it encourages outdoor living by not requiring the homeowner to dirty the enclosed living areas with sand and debris from outside.

2.13 Symbolic Inscriptions and Choice Materials

The individual materials of the home were selected to maximize textual and aesthetic experiences of the building. The entrance salon is made of local stone drawn from the limestone laden soil of the Yucatan. The door is composed to Tzalam, a beautiful local wood, sourced in the Yucatan peninsula. When gazing at the door, the viewer is drawn to both the entrance of the building and the columns adorning the sides of the door. Thus, the viewer enjoys Mayan accents within the Classical facade of the entrance salon [9]. The garden area of the home boasts inscriptions on the interior walls of courtyard. Additionally, perfumatic vegetation has been planted inside the garden to provide a shaded, pleasing, environment for relaxation. Throughout the home, the architects have visualized a coherent series of potted plants to bring vegetation into areas without soil.



Figure 3: The Frontal View of Casa Oleaje Showcasing the Materials Chosen and Merge of Classical and Mesoamerican Design

3. Results

The above methodology was adapted into a complete design for a villa as showcased in Figure 3 and Figure 4. The completed design presents a new opportunity for visitors to be encompassed in a completely unique, authentically bioengineered, space that encourages rest and recuperation. We believe that this style of architecture is novel and presents a new way of encouraging healthy living within an environment. By exploring new architectural avenues, a larger opportunity has been created to adapt these techniques to new environments where homes will be built.

4. Discussion

Completing this design required a multidisciplinary team of architects, regional experts, and human performance experts. This was a new engagement for the team and collaboration was key to creating the outcome. The team established a weekly meeting rhythm that was lead by Javier to work through each step of the design sequentially. The design process started with a conceptual framework where we imagined the different pathways that we could take. Subsequently, we drafted the floor plans and began our considerations of the various engineering aspects of the home. Finally, renders were drafted to explain the concept in visual detail. We believe that each section of the home works together in concert to create an architectural project that we can be proud of. The actual construction of the structure will be completed within the next 24 months. At the point of completion, we will be able to measure the biological metrics of visitors to Casa Oleaje to determine the size of the positive effect from our architecture. We hope that the effect will be material to further prove the worthiness of the design.

We considered a variety of alternative materials for the construction of the villa. Chukum, a material that is popular in Tulum, was chosen for the inner walls. This was done to keep in theme with the expectations of visitors to Tulum who stay in accommodations with this material [10]. In other parts of Mexico, plaster is more common material for the interior walls. In addition to this, various options for the construction material of the front salon were considered before settling on the natural stone. The stone was contrasted to textured concrete and chosen for its adherence to the natural landscape. In terms of architecture, the multilevel aspect of the interior living area was one of primary consideration. Initially, we debated including four bedrooms but decided to expand the scope of the master bedroom to allow for bathing in a tub that is exposed through glass to the vegetated exterior terrace. That way, the homeowner will have a spa like ambience within a large master bedroom and open bathroom area to allow them to experience the terrace. The various aspects of the design were considered using a holistic perspective. This way, we ensured that each part of the home had the benefit of health, performance, beauty, was on the architectural avant-garde, and encouraged natural living. With these aspects as our guiding principles, we were



Figure 4: The Garden Patio is Oriented to the Airflow Pattern on the Property Which Offers Natural Cooling. The Solar Chimney and Alternating Staircase are also Shown

Journal of Advances in Civil and Mechanical Engineering

able to create a uniquely crafted building that exists outside of contemporary time. The occupant of the building enters a space that transcends its surroundings and offers separation from modernity. Thereby, curing the occupant from modernity's various ills and misrepresentations.

5. Conclusion

In conclusion, we have successfully adapted modern science, nature, architecture and cultural heritage to create a space that stands outside of modernity. Henceforth, Casa Oleaje represents a timeless structure that can coexist with its surroundings yet exists outside of them. It's location, within the stunning biodiversity of the Riviera Maya, invigorates the structure with life. Serving to remind us that our bodies are intertwined with where we live. Therefore, the spaces that we inhabit should encourage the development of and enliven our passions for life. The design, though scientifically modern, is meant to heal rather than destroy. And the architecture encourages creativity by interacting with our minds using the latest knowledge available to us. Thus, Casa Oleaje is a place to nurture, heal, and help encourage the creativity that can be applied to the adventure of our lives.

References

- 1. Foll. Solar cell technology. Christian Albrechts Universitat zu Kiel.
- 2. Blue, M. (2024). Simulated historical climate weather

data for cancu'n. MeteoBlue.

- 3. Lee, Y., Lee, S., & Lee, W. (2023). Occupational and environmental noise exposure and extra-auditory effects on humans: A systematic literature review. *Geohealth*, 7(6), e2023GH000805.
- 4. Abbott, D. (2022). Understanding Sound, Chapter 45: Intensity and Distance. Pressbooks. *Accessed April, 7*, 2022.
- 5. Martellotta, F. (2021). Innovative composite materials for sound absorption and insulation: where we are and where we are going. *Materials*, *14*(8), 1954.
- 6. Kant, I., & Guyer, P. (2011). *Observations on the Feeling of the Beautiful and Sublime and Other Writings* (p. 203). Cambridge: Cambridge University Press.
- Aharon, I., Etcoff, N., Ariely, D., Chabris, C. F., O'connor, E., & Breiter, H. C. (2001). Beautiful faces have variable reward value: fMRI and behavioral evidence. *Neuron*, 32(3), 537-551.
- 8. Wechsler, D. B., & Bautista-Trigueros, A. (2011). Cosmopolitanism, Cubism and New Art: Latin American Itineraries. *Art in Translation*, *3*(1), 69-85.
- 9. Architecture.com (2024). Classical / classical revival / neo-classical. Architecture.com.
- Rodriguez-Navarro, C., Monasterio-Guillot, L., Burgos-Ruiz, M., Ruiz-Agudo, E., & Elert, K. (2023). Unveiling the secret of ancient Maya masons: Biomimetic lime plasters with plant extracts. *Science Advances*, 9(16), eadf6138.