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MASTER OF SCIENCE IN ARCHITECTURAL ENGINEERING

MASTER THESIS REPORT

Re-thinking CASTLE PINCKNEY for 21st Century

Charleston, South Carolina

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Thank you all,

Anna, Golnar, Nikyar

Abstract

Re-thinking Castle PINCKNEY for 21st Century:

Castle Pinckney, the oldest surviving fortification of Charleston city (South Carolina), has been forgotten for ages and declines continuously. A great effort has been started to find a proper solution to change current condition of the fort. This effort is aimed to reintroduce the forgotten castle and its unicity to inhabitants of Charleston city and tourists.

Facing the Reality:

Any effort to make Castle Pinckney accessible to the public, or to adaptively reuse the site, faces some obstacles. First and foremost is the fort's location, on an island in the harbor, requiring boat transportation to access the site. There is no utilizable dock on Shute's Folly Island. The island itself is low-lying and marshy, and covered with a dense low growth which is not amenable to pedestrian activities. The fort itself, its interior completely filled with earth, presents little of obvious, outward historic interest. Which structures or foundations may survive under the fill is unknown. Extensive archeology would be required in the fort's interior to expose these remains.

From Obstacles to Opportunities:

A reuse project of an old and monumental fort is not just a big and exciting challenge, but it also comes with great responsibility. The design should connect to the existing building but also provide something new and exciting. The general vision of this project is to emphasize the existing fort and give priority to that, instead of taking the attention from the old building to the new addition.

We believe after the realization of vital & required interventions to Castle Pinckney, controlled public access to the fort & island with the concept of an art gallery inside it not only won't alter the brick structure and possible remaining parts but also make it alive again. The fort is still unknown for city inhabitants and many people even do not remember that such monument exists and belongs to their history.

We think Castle Pinckney is not anymore a place to host cannons and soldiers. Instead it should be house of art, artists and visitors with an everlasting memory.

This thesis project aims to propose a well-studied idea and solution for both Castle Pinckney and Charleston City to reconnect the city with island. Thesis project starts with a comprehensive study about the city and fort and all their existing and future potentials. In next chapters it continues with architectural design and more technical analysis, required for a unique design.

A light wooden type of structure is designed for the Castle which has art gallery function. An existing pier in city waterfront has been selected to be developed. We proposed extension of the pier to create adequate space for a welcome center, boat station and an elevated restaurant with a panoramic view which creates a relaxing and desirable space for people who are interested.

Italian summary

Ripensando il Castello:

Castle Pinckney, la più vecchia fortificazione esistente di Charleston city (South Carolina), è stato dimenticato per secoli esitrova in forte stato di abbandono. Ungrande sforzo è stato fatto per trovare una soluzione appropriata per cambiare l'attuale condizione del forte. Questo sforzo mira a ripresentare il castello dimenticato e la suauni cità agli abitanti di Charleston e aituristi.

Confrontandosi con la realtà:

Ogni sforzo per rendere Castle Pinckney accessibile al pubblico o per riutilizzare il sito, fronteggia alcuni problemi. In primo luogo, la collocazione del forte su un'isola, richiede l'impiego del trasportomarittimo per recarvisi. Non esiste banchina utilizzabile sull'isola Shute's Folly. L'isola stessa sitrova ad un livello basso e paludoso, e coperto da un ovegetazione bassadensa, non favorevole per le attività dei passanti. Il forte stesso è completamente riempito di terra all'interno e mostra dall'esterno poco del suo valore storico. E' ignotoquali strutture o fondazioni esistano ancora sotto il riempimento. Scavi archeologici dovrebbe roessere effettuati all'interno per mostrare cosa sopra vive.

Da ostacolo ad opportunità:

Un progetto di riuso di un forte antico e monumentale non è solo una grande e stimolante sfida, ma anche una grande responsabilità. Il progetto dovrebbe connettersi all'edificio esistente, ma offrire in più qualcosa di nuovo e deccitante. La vision generale del progetto consiste nell'enfatizzare l'edificio esistente e dare a ciò la priorità, invece di sottrarre l'attenzione a quello storico per focalizzarsi sull'aggiunta.

Noi crediamo che dopo la realizzazione di quest'intervento vitale e necassario al C P, un accessopubblico controllato al forte e all'isola, con l'idea di una galleria d'arte all'interno, non solo non altererà la struttura in mattoni e le alter possibili partiri maste ma gli restituirà nuova vita. Il forte è ancora sconosciuto per gli abitanti della città e molte persone non ricordano nemmeno che questo monument esistene a loro storia.

Noi riteniamo che Castle Pinckney non sia più un luogo per ospitare cannoni e soldati. Dovrebbe al contrario essere una casa per l'arte, gli artisti, e i visitatori nel tentative di fornirgli una memoria imperitura.

Questo progetto di tesimira a proporre una idea ben studiata e unasoluzione sia per Castle Pinckney che per Charleston City per riconnettere la città con l'isola. La tesi inizia con uno studio approfondito circa la città e il forte e tutto il suo potenziale presente e futuro. Nei capitol successivi continua con il progetto architettonico e analisi tecniche più dettagliate, necessarie per creare un design unico.

Una struttura leggera di legno è stata progettata per il Castello come galleria d’arte. Un molo esistente sul lungo mare della città è stato scelto per essere sviluppato. Noi abbiamo pensato all’estensione del molo per creare uno spazio adeguato per un centro d’accoglienza, una stazione per le imbarcazioni e un ristorante sopra elevato con una vista panoramic che crea uno spazio rilassante e dinvitante per le persone interessate.

“With special thanks to Miss *Lisa Scaglione* for Italian translation”

Chapter 1

Introduction

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Introduction

1. Competition Introduction

The 2012 international Preservation as Provocation Ideas Competition challenges students and multi-disciplinary teams in architecture, preservation, landscape architecture, urban planning, engineering and other cross-disciplines, to rethink Castle Pinckney, an abandoned early nineteenth century fort situated on a coastal island within the Charleston, South Carolina, harbor. The brick fort is situated within close proximity of Charleston, one of America's most significant and popular historic cities, and is clearly visible from the city's waterfront. Participants in the competition are asked to preserve, interpret and reimagine the extant historic fabric as emblematic of the country's early attempts to create a federal defense system and the site as an eco-tourist and educational destination. Solutions are encouraged to explore off-grid energy consumption, access, the relationship between preservation and design, landscape design, changing climate patterns, water management, underutilized land use, habitat protection, heritage tourism, and the design of public space. The competition is organized by the **American Institute of Architects Historic Resources Committee** (AIA/HRC) along with the **Association of Collegiate Schools of Architecture**, funded by the **National Center for Technology and Preservation and Technology Training** (NCPTT), a unit of the National Park Service with additional sponsorship by **Clemson University/College of Charleston Graduate Program in Historic Preservation**.

Castle Pinckney is evocatively situated within the view shed of one of the nation's most historic and well preserved cities, yet its history and significance is virtually unknown to the citizenry at large. Respecting the natural beauty of the site along with the historic integrity of the fort, the design challenge is to identify a use for this former island fort, Confederate prison and now defunct lighthouse station. More ambitiously, the students should investigate how the preservation of this historically significant fort, can provoke a profound rethinking of our current conventions about preservation, design, community, environment and heritage tourism.

1.1. The Purpose

In today's professional practice, responsible design is increasingly acknowledging the layers of architectural memory to provide continuity in our fast changing culture. Existing and historic buildings and sites are an expanding segment of architectural practice. Such projects demand an insightful response to physical and social contexts. The goal of this competition is to explore how collaboration between historic preservation and design can produce uniquely thoughtful and creative solutions to the aesthetic, technical, cultural, spiritual, economic, and climactic challenges of our times.

Maps, measured drawings, photos and the history of the Castle Pinckney site will be provided to explain the significance of this island property. Variations in the meaning and values of the site help to enrich the design problem at heritage sites. The existing material evidence of the fort should be preserved as part of the solution to convey the authenticity to future generations but alterations to the building fabric may be explored in response to proposed new uses.

1.2. Castle Pinckney

Castle Pinckney (*Picture1*), the oldest surviving fortification in Charleston, South Carolina, was built in 1809 on a small island in the city's harbor. It remains one of only three surviving examples of an American "castle," a rare type of transitional coastal fort, circular in form and lacking angular bastions. The fort played a minor role during the American Civil War and was subsequently decommissioned, passing through the jurisdiction of a number of different government agencies over the past 150 years. Due to lack of funding, Castle Pinckney has essentially languished in abandonment for over a century. In 2011, as a mitigative and educational effort, to bring public attention to a significant endangered resource, a documentation project was undertaken by the Historic American Buildings Survey and by the Master of Science in Historic Preservation program of Clemson University / College of Charleston. Building on this effort, this student design competition is being held to explore ideas for the adaptive reinvention of the site.

Figure 1.1, Shutes Folly Island, Castle Pinckney

Castle Pinckney was built of brick masonry construction, with its exterior walls approximately 15' (4.5 m) in height and approximately 7'-6" (2.3 m) thick at the base. In plan, the fort was closely related to the design of **Castle Clinton** located in New York (*Picture 2*), laid out in the general shape of a "half-moon," with a 165' (50 m) diameter. The sweeping, rounded section of the fort, oriented south toward the mouth of the harbor, contained eight casemates for cannon. Additional artillery was to be mounted en barbette on the terreplein above. The straight section of wall along the north side of the fort was flanked by two shallow, curved bastions, each with two levels of gun embrasures to provide protection for the centrally-located sally port. Barracks and officers' housing were located on the interior, along the north wall section.

Figure 1.2, Castle Clinton, New York

1.2.1. Castle Pinckney 1811-1861

Although built to accommodate up to 200 men, Castle Pinckney was rarely occupied by more than 20 soldiers during the first few decades of the nineteenth century. No action occurred in Charleston during the War of 1812. Over the succeeding years a number of subsidiary structures, including a small hospital, a carpenter's shop, and a smithy, were constructed to the north side of the fort. In the early 1830s, the yard on the north side of the fort was enclosed by a wooden palisade. As early as 1826, however, Castle Pinckney was being referred to as an "auxiliary," rather than primary, component of Charleston's harbor defenses. And with the commencement, in 1829, of the construction of the larger and more substantial Fort Sumter, a permanent system fort at a more strategic location near the mouth of the harbor, Castle Pinckney's impending obsolescence was made evident.

1.2.2. Castle Pinckney during the Civil War

On 20 December 1860, South Carolina became the first state to secede from the Union, precipitating the American Civil War (1861-65). Seven days later, in one of the first hostile actions of the incipient conflict, Castle Pinckney was seized by local secessionists, who overwhelmed its small federal garrison. The fort was then occupied by South Carolina militia. Following the First Battle of Manassas in July 1861, Union prisoners were brought to Castle Pinckney, and housed there until their exchange in October of that year. Over the subsequent course of the war, Castle Pinckney's exterior walls were reinforced with massive earthen berms on both the interior and the exterior to resist bombardment, as the fort served an integral role in the Confederate defense of Charleston Harbor.

1.2.3. Castle Pinckney, 1865-2011

A light beacon had been installed at Castle Pinckney in 1855 and, following the end of the War, the fort, by then officially obsolete as a military post, was transferred from the Department of War to the Lighthouse Bureau of the Department of the Treasury in 1878 for use as a supply depot. During the 1880s a large warehouse was constructed on the filled-in fort, connected by a railroad trestle to the island's wharf, along with a house for the lighthouse keeper and his family. In 1917 Castle Pinckney was de accessioned by the Lighthouse Board and returned to the Department of the Army, under the control of the Corps of Engineers. Castle Pinckney was designated a National Monument in 1924, and transferred to the control of the National Park Service (NPS) in 1933. The NPS, however, lacked funds for restoration and deemed the fort of minor historical importance. In 1956 the fort's National Monument status was revoked by Congress. That same year the South Carolina State Ports Authority assumed jurisdiction over Shute's Folly Island. In 1967 the warehouse and residence were destroyed by fire. Although a number of proposals for development of the island and the fort were put forward during the second half of the twentieth century, all failed due to lack of funding.

1.2.4. Current conditions

The future of Castle Pinckney remains uncertain and problematic. In 2011 the fort was sold by the SPA to the Sons of Confederate Veterans (SCV) but any proposal to use Castle Pinckney to promote the Confederate cause would undoubtedly be controversial for a large segment of the American public. ????

In any case, the effort to make Castle Pinckney accessible to the public, or to adaptively use the site, faces significant obstacles. First and foremost is the fort's location, on an island in the harbor, requiring boat transportation to access the site. There is no dock on Shute's Folly Island. The island itself is low-lying and marshy, and covered with a dense low growth which is not amenable to pedestrian activities. The fort itself, its interior completely filled with earth, presents little of obvious, outward historic interest. Which structures or foundations may survive under the fill is unknown. Extensive archeology would be required in the fort's interior to expose these remains.

Although the walls of Castle Pinckney have survived relatively intact, especially considering its exposed location, there are unmistakable signs of slow, steady deterioration. Large cracks can be seen in the walls in several locations, and there are a number of locations where bricks have fallen out.

Vegetation remains a problem, with numerous plants, and even trees, growing out of the top of the walls. Charleston is prone to hurricanes, with the city suffering, on average, one a decade. Hurricane Hugo in 1989 caused seven billion dollars in damage and 26 deaths. Likewise, the rise in sea level due to global climate change will undoubtedly have an adverse impact on Castle Pinckney. Although the seaward side of the fort is protected with rip-rap put in place by the State Port Authority, water at high tide nonetheless reaches the bottom of the fort's walls.

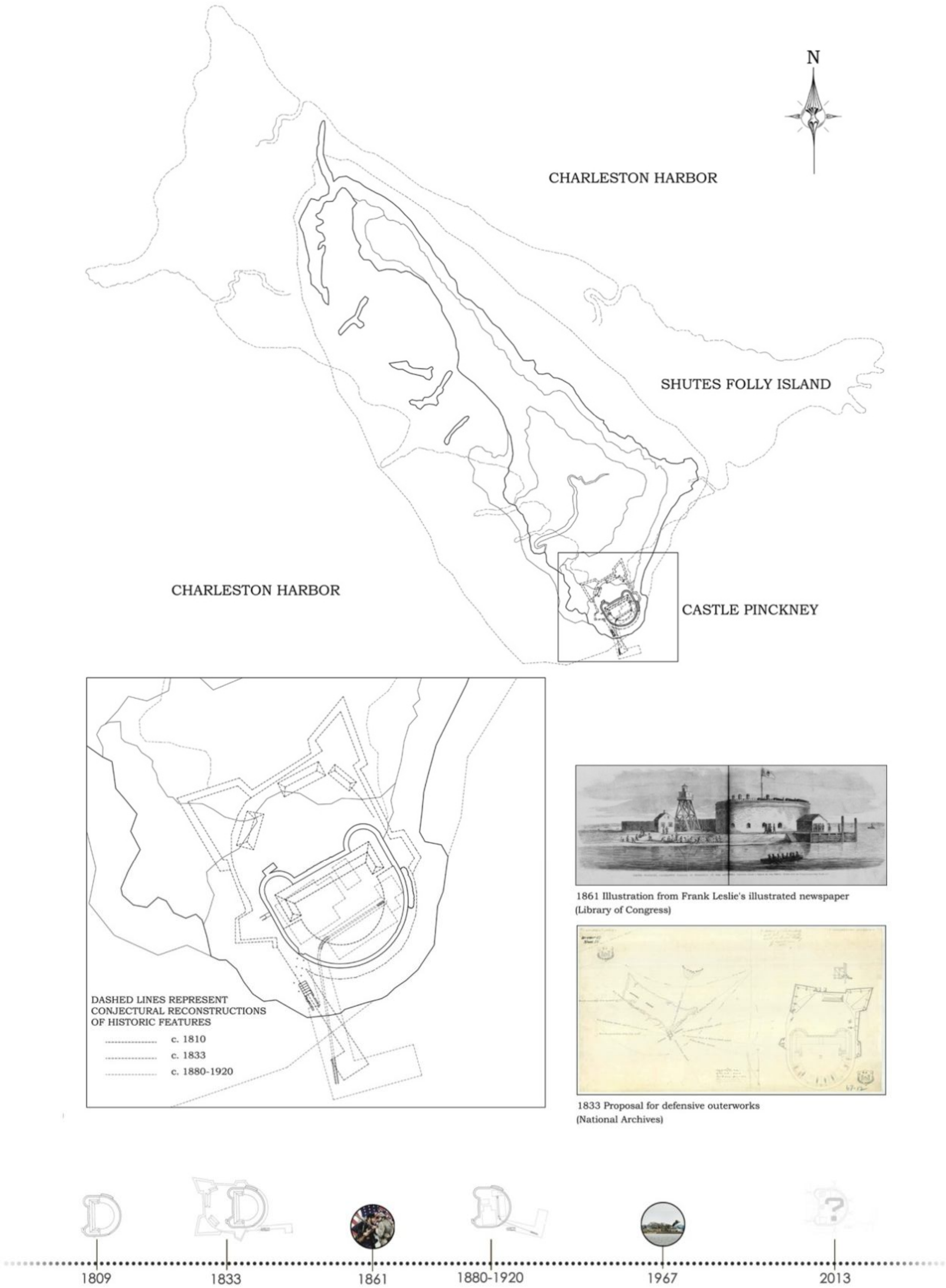
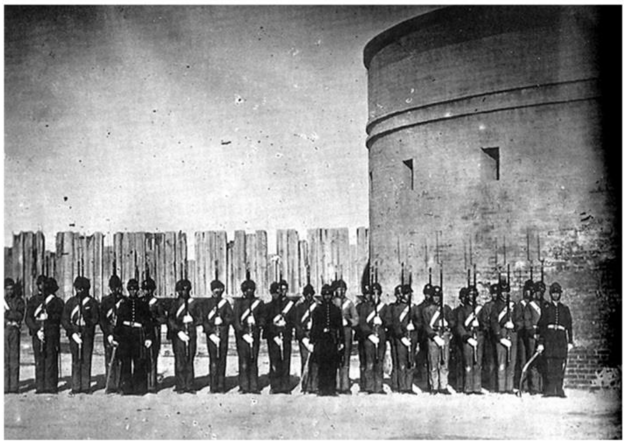
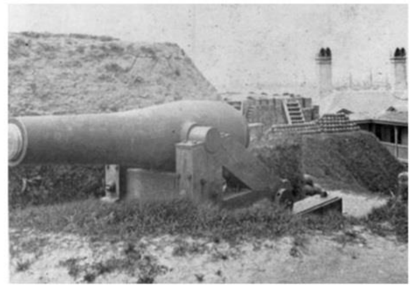
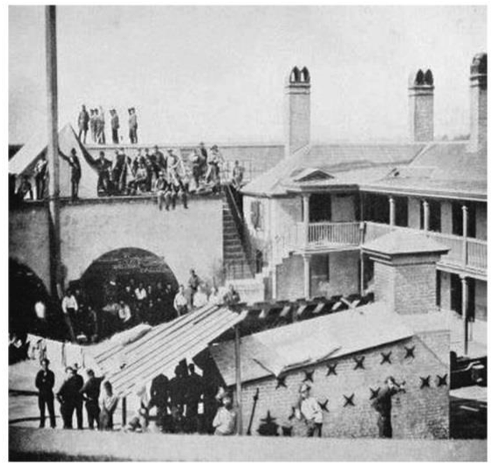
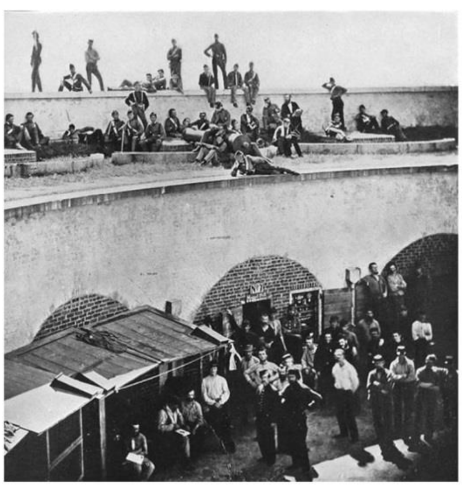


Figure 1.3, Castle Pinckney along the history









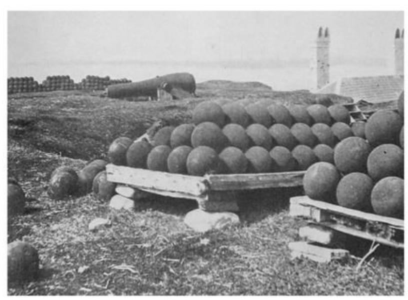


Figure 1.4, historical pictures showing situation of the Castle in the past

1.3. The Challenge

Re-think | Re-imagine | Reuse | Repurpose | Reinvent | Rebuild

This competition is intended to challenge students in multi-disciplinary teams in the fields of architecture, preservation, landscape architecture, urban planning, engineering and other cross-disciplines, to rethink the abandoned early nineteenth century fort. Participants are asked to preserve and interpret the extant historic fabric as emblematic of the country's early attempt to create a national defense system, and should re-imagine the site as an eco-tourist and educational destination. The island is being reformed into public space that boosts local character with the capacity for everyday or crowd-pulling events. Solutions should explore the issues of access, the relationship between preservation and design (both architectural and landscape), off-grid energy consumption, changing climate patterns, water management, land use, and habitat protection. Participants should investigate how the preservation of this historically significant site can provoke a profound rethinking of our current conventions about preservation, design, community, the environment, and heritage tourism.

1.4. Program Requirements

- Island Access / Dock / Harbor

Access to Shute's Folly Island is by water. This access needs to accommodate small motor crafts, sailing vessels, kayaks, water taxis, and harbor cruise boats, with multiple mooring stations along a landing pier or areas.

- Welcome Pavilion

A self-sustaining (off-the-grid) visitor service pavilion which must contain information on the island, require no attendant or staff and no maintenance restroom facilities.

- Belvedere

A building, architectural structure, or platform designed and situated to take advantage of the scenic views of the Charleston, the harbor, Castle Pinckney, the island and nautical events in the harbor such as regattas.

- Landscape

The evocative Low country landscape should be crafted to create views, habitats, trails and activity areas. The island is flat and marshy and covered with low-growth vegetation. .

- Castle Pinckney

The fort located on the far end of Shute's Folly Island can be reinterpreted, reused, or left as an archeological site. The materials of the ruins should be protected and maintained.

- Be Creative

How will local residents and tourists use Shute's Folly Island and Castle Pinckney? Performance Space, Art Installations , Marine Biology research, Costal Conservation/Rejuvenation, Tourism, Ecological Preserve, fisherman huts, regatta watching platforms, lookouts, nautical and recreational activities, business premises for nautical events.

Chapter 2

Sustainability

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Sustainability

Sustainability means that things can keep going, can sustain themselves, can continue into the future and go on forever. From a human perspective, sustainability for our planet means that it can continue to do what it was designed to do. Provide fresh air, clean water, produce food and allow us to have a high quality of air forever. But sustainability means that it cannot and that is where we are now. 20 years ago scientist from Sweden developed the definition for sustainability with 4 basics principles. These can be seen as the main instruction for our plant. If we follow them, it is good for our planet and as we are in a system that is our plane, it is good for us as well. These 4 main instructions are as follows: 1- reduces our dependence on fossil fuels and heavy metals. 2- Reduce our dependence on synthetic chemicals that influence the nature 3-reduce our destruction of the nature and 4- sure we are not stopping people globally from meeting their needs. Demand for earth services, clean air, water, food increases as population increases and living standards rise. But earth serviceability to provide these needs is decreasing because of the way we are living. The human being has become a threat to our own way of life. The earth is a system and everything is connected: Society, Environment and Economy. To live sustainably we need to follow these already mentioned strategies and apply to everything we do at home, at work and every aspect of our life. If we follow these together we will have a better quality of life, waste less and pollute less.

2. Sustainability Plan, Charleston green plan

Sustainability is understood to mean the ability of current generations to meet its needs while not diminishing the ability of future generations to meet their own needs. The goal of the Charleston Green Plan is to continue Charleston's shift to a more sustainable and profitable future for both current and future generations.

A sustainability plan is a comprehensive roadmap, with many options, for the City to embrace sustainable practices: through its internal operations, its leadership by example and its education and inspiration of its citizens. It lays a foundation for the City's efforts. The Green Committee presents this plan for the purpose of offering advice, information and strategies to achieve the City's and its citizen's goals of more jobs and less pollution. A team of dedicated City staff served on each subcommittee and offered technical and practical advice on the impact and value of the plan's recommendations. An inventory of the municipal and community-wide operations and emissions accompanies the plan, as well as a proposed metrics for measuring the City's efforts.

The lush lands of the Low country with its complex network of estuaries and wetlands and rich biodiversity has long drawn people to the Charleston area. For centuries, the native inhabitants of the Charleston area found abundant natural resources, and their communities prospered in relative harmony with nature. Before the Civil War, wealth from rice, lumber, and trade transformed Charleston into a prosperous community.

Today, the abandoned rice fields attract wildlife, and Charleston's wealth is preserved in its historic buildings and landscape. Charleston's history is intertwined with the lushness of the Low country environment, and this historical reliance on the environment has led to a culture of preservation and a respect for nature. As a consequence, we live in a beautiful environment where wild places abound. Charleston is the home to ancient trees, dolphins, endangered birds, bald eagles, rich wetlands, coastal forests, sea turtles nesting on the beaches, and lush gardens. Historic preservation and environmental conservation draw people to the Low country, swelling Charleston's population. Population pressure for more land and resources and global changes have compelled Charleston's citizens to develop a sustainability plan to meet these challenges.

2.1. The Big Picture

Human induced global changes touch every aspect of our world and alter the earth's chemical and physical cycles. These changes to the earth's biogeochemistry are causing global temperatures to rise and altering nutrient cycles that we depend on for our food and water. To prevent continued damage to the earth's ecosystems and to preserve the Low country environment, climate protection and sustainable development require our urgent attention. Because of the global nature of the problems facing Charleston, our citizens must act with others throughout the world to effectively protect our community and other communities undergoing unwanted environmental changes.

In 2007, the Intergovernmental Panel on Climate Change (IPCC) issued its latest report on the state of the world's climate that concluded, with better than 90% confidence, that human activity has caused most of the observed climate change within the last fifty years. The overwhelming scientific evidence shows that temperatures are rising; that permafrost is thawing; those glaciers, icecaps, snow pack, and sea ice are melting; that sea level is rising; and that storm events, including hurricanes are becoming more severe. The significance of these scientific findings, presented by 1,250 authors and 2,500 reviewers from

130 countries, forced nations to face up to the need to put policies into place to reduce the projected rise in greenhouse gases and the concurrent increase in global temperatures. The rate and the degree of climate change will depend on the extent to which we decrease global emissions of carbon dioxide and other heat trapping gases. No reputable scientific society has disputed the IPCC's conclusions, and the Committee won the Nobel Peace Prize for the quality of its work on these issues. Global climate change will alter rain patterns causing both an increase in flooding and drought events, which would make potable water increasingly scarce in many parts of the world and decrease the productivity of croplands. Increasing temperature and changing precipitation patterns will dramatically alter terrestrial and aquatic ecosystems. Changes to ecosystems will provide opportunities for a new cohort of pests to invade agricultural lands and forests.

Rising sea level will adversely impact energy and transportation infrastructure and make many coastal communities uninhabitable. Water scarcity, heat stress, and invasion of new vectors of disease will increase illnesses and have a negative impact on human health. "The projected rapid rate and large amount of climate change over this century will challenge the ability of society and natural systems to adapt." In some cases, plants and animals will not be able to adapt fast enough to the projected climate changes - one million species may become extinct by 2050. As serious as climate change is, however, it cannot help but have some positive consequences. Already we are seeing unprecedented levels of international cooperation, effective government, youth leadership, and individual involvement.

Further, the threat of climate change is driving exciting advances in technology, and also opening up economic opportunities that were previously unthinkable.

These include everything from a new generation of super-efficient household appliances, to the possibility of capturing and using waste heat from industries, to the burgeoning market for wind energy, which is particularly appropriate for use in South Carolina. At the same time, millions of new jobs are projected worldwide as a consequence of climate change -- including three million new jobs related to clean energy technology in the US alone. As with any great challenge, climate change raises serious concerns, and also creates new opportunities. Both globally and locally, our response to this situation is limited only by our imaginations.

2.2. Closer to Home

Climate change is expected to have a significant impact in Charleston as well. Average annual temperatures in the region have risen about 2 degrees Fahrenheit since the 1970s. They are projected to rise 4.5 to 9 degrees more by 2080, depending on how much we reduce the global greenhouse gas emissions that are causing temperatures to rise. Moreover, with about 8% less rain each year since the 1970s, droughts in the region have increased, and are expected to intensify with higher temperatures. Some of the anticipated consequences in the area around Charleston include decline in urban air quality; degradation of water resources and decline in water quality; decline in forest growth and agricultural crop production; decline in production and/or increased costs of raising livestock; increased wildfires and pest outbreaks; and decline in water quality.

3 key consequences of climate change in the Charleston area:

• More intense Atlantic hurricanes;

• More torrential rainfalls;

• Rising sea levels and associated coastal flooding and shoreline retreat.

In Charleston and elsewhere, heat, drought, hurricanes, torrential rainstorms, and sea level rise are expected to interact synergistically with population growth and ongoing environmental stresses. In other words, the whole climate protection and sustainability challenge is expected to be greater than the sum of its parts.

According to a major federal study: Climate change will combine with pollution, population growth, and overuse of resources, urbanization, and other social, economic, and environmental stresses to create larger impacts than from any of these factors alone. The population of the tricounty area has grown 54% since 1990, and is projected to increase another 38% by 2030.

2.3. Sea level rising

In the past, sea level has risen in Charleston at the rate of 1.03 feet per century18 which is greater than the global rate reported by the IPCC of 0.55 feet per century. Between now and the year 2100, global sea level is expected to rise between 1.6 feet and three 3 to 4 feet.20 No predictions for the future are available specifically for Charleston. If current trends continue, local sea level rise will continue to be greater than global sea level rise. Clearly the City’s low-lying areas are fairly close to sea level. Sea level rise is considered “one of the most certain and most costly consequences of a warming climate.” High costs are expected from increased erosion, storm surge damage, and flooding. If present trends continue, the annual cost of hurricane damage in the Southeast is expected to rise from $10 billion in 2025 to $422 billion in 2100. The annual cost of real estate losses in the Southeast is expected to rise from $34 billion in 2025 to $360 billion in 2100.

2.4. Next Steps

Recognizing that Charleston has taken many positive steps in this area, the plan lays out further steps necessary to meet the City’s goals and commitments.

2.4.1. City Buildings

The City should commit to continuing to meet higher sustainability standards as they are developed with all municipal buildings. This includes development of separate sustainability guidelines for historic structures. All city facilities should become visible, accessible sources of inspiration and leadership on how to implement sustainable building practices for Charleston residents, visitors, and other government entities.

2.4.2. Private Property Owners

The City should actively encourage private property owners to meet the same high standards of sustainability. Expanding sustainable building in the private sector will require offering meaningful incentives, such as fast-track permit review and waivers of density and other requirements. It will also require effective public relations and community outreach.

Energy Efficiency Partnership:

The City is currently helping to create a “one stop shop” public-private partnership that will help home and business owners increase energy efficiency through weatherization and conservation measures. Beginning in 2010, this partnership should raise the capital for a revolving loan fund, educate home and business owners, install and insure the improvements, and offer practical financing. This plan calls for the city to remain a key leader, partner, and facilitator in this undertaking.

Funding for Sustainable Projects:

Financial institutions are often not familiar with sustainable building practices. Nor do they know how to value sustainability over a building’s life cycle. The City should work with lenders, appraisers, investors, and state and federal agencies to identify and increase financing opportunities, and advertise these opportunities on its website.

Historic Preservation and Sustainability:

Recognizing the need to address green building practices in historic structures, the Historic Preservation work group of the Buildings Subcommittee developed guidelines for homeowners and businesses to help them make the most energy saving choices.

2.5. What is green?

- ENERGY

Green buildings use energy efficiently and often rely on renewable energy resources. They maximize the sun’s warmth in winter and maximize shade in summer. They are airtight and well insulated. They also use energy efficient systems and appliances, and plenty of natural light. When buildings are designed in this way, energy consumption can be reduced by 50% or more at little or no extra cost.

- ENVIRONMENTAL IMPACT

Green buildings are made of materials that require less energy to harvest, manufacture, and transport. They often include permeable paving that lets storm water drain naturally through the soil, rather than pouring it unfiltered into surrounding waterways. They also use landscaping that needs little extra water or maintenance, including native plants. Note: well-designed landscaping can help reduce air conditioning energy consumption by 75%, and can increase property value by as much as 15%.

- RESOURCE CONSERVATION

Green buildings often use recycled, reused, or rapidly renewable materials. They also minimize construction waste. Another important feature is efficient plumbing -- which, along with appropriate

landscaping, can reduce water use by 30%. Sometimes these structures include a “green roof,” which is covered with soil and plants. This reduces energy consumption and storm water runoff, and can protect clean air and provide wildlife habitat.
Sometimes these buildings also include “grey water systems,” which recycle water from sinks and bathtubs into the landscaping.

- INDOOR AIR QUALITY

Green buildings are airtight to minimize the entry infiltration (leaking in) of unconditioned, unfiltered outside air that can cause health problems for building occupants and moisture - related problems for the buildings themselves in buildings and control natural ventilation.
When a building is airtight special care must be taken to make sure that the air inside is clean and well ventilated. This is accomplished by using nontoxic building materials and superior ventilation systems that control the amount and quality of outside air introduced into a building.

- COMMUNITY IMPACT

Green buildings are often located within easy access of public transportation and/or in communities where it is easy to walk or bicycle to nearby stores and services. They link to existing roads and waterlines and connect people to readily accessible services such as shopping for food, banking, and health care providers rather than sprawling into the countryside, where there is little infrastructure to sustain them.
Also, green buildings blend into the community, preserving natural and historic features.

Better Buildings Goals, Actions & Recommendations

- ACTIONS

1. Require new City-owned buildings and renovations to non-historic existing City-owned buildings to be sustainable.
A. Set specific performance targets for site selection, water conservation, energy and atmosphere, materials and resources, indoor environmental quality, and operations and maintenance.
B. Meet the energy reduction targets of Architecture 2030.
2. Historic buildings are inherently sustainable. Require modifications to historic City-owned buildings to follow current best practices with regard to integrating historic preservation with modern sustainable practices.
3. Encourage private sector to adopt voluntary sustainable building practices.
4. Encourage disclosure of utility data and building performance.
A. Disclose utility data for each City building annually, with comparisons to the previous year and to regional or national benchmarks.
B. Encourage sellers of private property to provide utility data for the previous twelve months.
5. Develop a weatherization program.

6. Help increase financing options.

7. Focus on public outreach.

A. Develop an aggressive, comprehensive, and multifaceted communications and public education campaign.

B. Implement the campaign in collaboration with local partners, developing Sustainable Design Workshops and Green Building Seminars.

Cleaner Energy Goals, Actions & Recommendations

- ACTIONS

1. Establish an “Efficiency-First” principle.

2. Use energy efficiently.

A. Increase the conservation of electricity,

B. Develop energy-efficient procurement standards for the City.

C. Continue to use energy service companies.

D. Create a Charleston Climate Partnership with major energy consumers.

E. Establish an alternative financing program to facilitate energy efficiency.

F. Study the implementation of a four-day workweek.

3. Generate and support renewable energy.

A. Set a goal for renewable energy.

B. Helps develop large-scale sources of renewable energy.

C. Encourage on-site generation of renewable energy on City and private property.

- ACTIONS:

1. Establish an “Efficiency-First” principle.

2. Use energy efficiently.

A. Increase the conservation of electricity,

B. Develop energy-efficient procurement standards for the City.

C. Continue to use energy service companies.

D. Create a Charleston Climate Partnership with major energy consumers.

E. Establish an alternative financing program to facilitate energy efficiency.

F. Study the implementation of a four-day workweek.

3. Generate and support renewable energy.

A. Set a goal for renewable energy.

B. Helps develop large-scale sources of renewable energy.

C. Encourage on-site generation of renewable energy on City and private property.

4. Transmit and deliver electricity efficiently.

5. Encourage the public to participate.

E1. ESTABLISH AN “EFFICIENCY-FIRST” PRINCIPLE

Summary of Specific Issues: Population growth and new technologies have increased energy demands, and consequently greenhouse gas emissions. Energy efficiency is the most cost effective, cleanest, and quickest way to reduce energy consumption and decrease greenhouse gas emissions.

Recommendation/Strategy/Action Plan:

The City should establish an "Efficiency First" principle to guide all of its energy use decisions. This principle should influence energy contracts (Recommendation E-2A) and purchases of equipment and supplies (Recommendation E–2B).

The Efficiency First principle should guide decisions about buildings and land use. (See Buildings Section and Recommendation B1) The success of an “Efficiency First” principle depends on City employees' general understanding of the costs and benefits of selecting energy efficient items.

Estimated Greenhouse Gas Reductions to be Achieved – In Metric Tons/Year: Probably substantial.

Implementation Responsibilities/ Assignments: The Sustainability Director should create a program to educate City employees about the "Efficiency First" principle.

2.6. Theoretical Framework

In this chapter we are challenging the process of USA sustainability model evolution. This factor affects the conceptual development of our proposal for Charleston.

The abstract model of sustainability concept is seen as a triangle of competing interests. It proposes that sustainable development is achieved through the self-conscious balancing of three competing interests within society; those of economic development, environmental preservation and social equity.

There is an assumption that sustainable concept is historical (or political), rather than scientific.

We are considering different historical periods listed below:

1) 1960's - the period that catalyzed public concern over the degradation of “nature”- the environmental movement recognized only two diametrically opposed interests, those of ecological integrity and economic development. In this initial opposition activists pitted themselves against the interests of economic development so as to preserve ecological integrity.

2) The mid-1980's - the period for most North Americans to recognize that the process was not only aimed to support interests of business and nature that were impacted by development. It is characterized by the recognition that

The relatively poor were being adversely impacted both by those who would consume natural resources and by those who would preserve them.

3) The latest 1990's - triangulated concept has been generally accepted as the logic that informs the concept of sustainable development. As a result it has been adopted by many institutions as the a priori tool through which sustainable development is first conceptualized and then measured.

We are considering three case studies of American cities that are associated in the literature with sustainable urban development and are listed in the U.S. and Canada Green City Index.

City Evaluation Categories:

Air

CO2

Buildings

Energy

Environmental governance

Land use

Transport

Waste

Water

We are considering one building in each following city that complies with LEED Platinum score:

1. San Francisco
2. Vancouver
3. New York

2.6.1. California Academy of Sciences
San Francisco, California
Museum

A glass-and-steel trellis incorporates 60,000 photovoltaic cells that generate electricity and help shade the building perimeter.

The trellis photovoltaic cells are expected to generate 220 KW of electricity annually, enough to power lighting for a rain forest and coral reef exhibit.

Figure 2.1, 2.2, California Academy of Science, San Francisco

- LEED Rating:
Platinum

- **Key Parameters:**

Completed: September 2008

Annual purchased energy use (based on simulation): 103 Kbtu/Ft2 (1,160 Mj/M2), 12% Reduction from Base Case

Annual carbon footprint (predicted): 18 Lbs. CO2 /Ft2 (87 Kg CO2 /M2)

Program: Museum, Planetarium, Aquarium, Laboratories, Collections Storage, Offices

✓ Photovoltaic cells to generate the electricity.

✓ Skylights, designed to open and close automatically, provide natural light to the interior halls.

2.6.2. West Building VCC
Vancouver, Canada
Exhibition Halls

Outside walkways provide access to the waterfront. One can see long distances into the harbor and out to the sea. The interior of the lobby uses locally harvested British Columbia wood on the walls and ceilings.

Figure 2.3, 2.4, wood on the walls and ceilings of West Building VCC, Vancouver, Canada

- LEED Rating:
Platinum

- **Key Parameters:**

Completed: April 2009

Annual purchased energy use (based on simulation): 41 kBtu/ft2 (460 MJ/m2), 59% reduction from base case

Annual carbon footprint (predicted): 1.4 lbs. CO2/ft2 (6.7 kg CO2/m2)

Program: Exhibition halls, meeting rooms, ballroom, retail, plaza, bicycle and pedestrian paths

- ✓ Access to the waterfront.
- ✓ Use of local materials.

2.6.3. Queens Botanical Garden
Queens, NY
Museum

The visitor and administration center comprises a two-story bar-shaped building, a winglike canopy, and a partially underground auditorium. The project celebrates water with features such as a winglike canopy that directs a cascade into a catchment basin when it rains.

Figure 2.5, 2.6, Queens Botanical Garden, New York

- LEED Rating:
Platinum

- **Key Parameters:**

Completed: September 2007
Annual purchased energy use (based on simulation): 41 kBtu/ft2 (469 MJ/m2), percent reduction from base case
Annual carbon footprint (predicted): 12 lbs. CO_2/ft2 (60 kg CO_2/m2)
Program: Visitor center, auditorium, administrative offices

- ✓ Use of horizontal wooden slats that shades interior during summer and help warm the rooms inside during winter by the controlling sun's trajectory means light can pass.
- ✓ Photovoltaic panels to generate the electricity.

2.6.4. Circular Congregational Church Addition
Charleston, South Carolina

- **Key Parameters:**

Location: Charleston, SC (on the Atlantic Coast at the confluence of the Ashley and Cooper rivers)

Annual purchased energy use (based on simulation): 16.5 kBtu/ft^2 (187.4 MJ/m^2)

Annual carbon footprint (predicted): 5.8 lbs. CO_2/ft^2 (24 kg CO_2/m^2)

Program: Classrooms, porches, exterior courtyard, nursery, meeting rooms

Figure 2.7, Circular congregational church addition, Charleston, South Carolina

Other examples of Sustainable Project in South Carolina that have achieved LEED Platinum certification are listed below:

• Half-Moon Outfitters Distribution Center, North Charleston, SC (LEED NC v2.2)
• Private residence (Paradise Upstate), Central, SC (LEED H)
• Private residence (AmeriPanel Homes of SC), Chapin, SC (LEED H)
• Private residence (Meadors Construction), Charleston, SC (LEED H)
• Private residence (Bay 10 Ventures), Hilton Head, SC (LEED H)
• Private residence (Maritime Green Builders), Myrtle Beach, SC (LEED H)
• Private residence (BRZ), Spring Island, SC (LEED H)
• Upstate Forever adaptive reuse, Greenville, SC (LEED NC v2.2)
• U.S. State Department's Charleston Regional Center, Charleston, SC (LEED NC v2.2)
• Wofford College, Glendale Shoals Environmental Studies Center, Glendale, SC (LEED NC v2.2)

Chapter 3

Urban Design

Chapter 3

Urban Design

3.1. Study and Analysis:

3.1.1. Site Location

Charleston**,** *the Holy City,* is the second largest city in the U.S. state of South Carolina and also the largest business and financial center for the Southeastern section of South Carolina. This city is the only city in United States with the zoning law.

Known for its rich history, well-preserved architecture, restaurant community, and mannerly people, Charleston has received a large number of accolades, including "America's Most Friendly City" by *Travel + Leisure* in 2011 and in 2013 by *Condé Nast Traveler*, and also "the most polite and hospitable city in America" by *Southern Living* magazine.

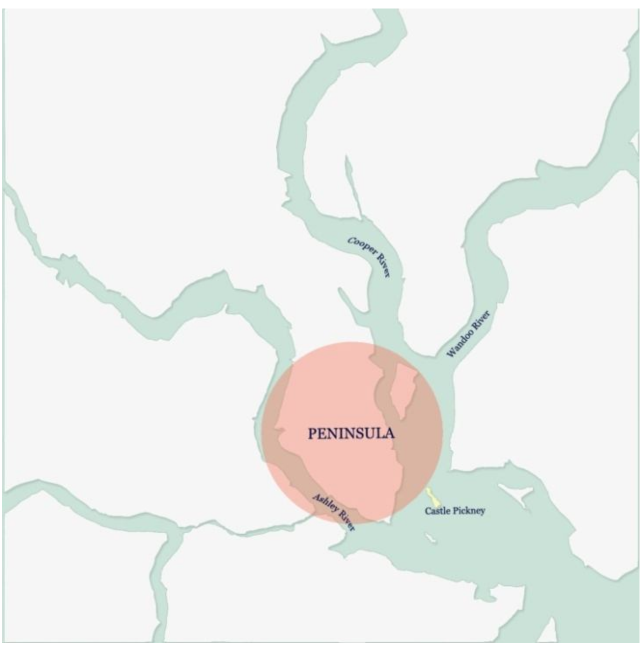


Figure 3.2, Location of the Charleston city and the peninsula

Figure 3.1, Location of Charleston in the U.S.

The old city is located on a peninsula at the Shores of the juncture of the Ashley and Cooper Rivers, where they form the Atlantic Ocean. It occupies 88.14 square miles, 7.6 square miles of a vital, downtown which is home to the City’s central business district. Dense urban streets set in dramatic contrast to the vast expanses of marsh which lay in buffer around the highlands.

City of Charleston is comprised of five distinct land masses (the Peninsula/Downtown, West Ashley, Johns Island, James Island, and the Cainhoy Peninsula) and each of these land masses has unique attributes and development patterns.

1. The Peninsula → the historic core of the Charleston;
2. West Ashley → home to some of the first post WWII suburbs, it is the City's largest and most populated area that first saw annexations in the1960s;
3. James Island → also home to post WWII suburbs, it is the City's smallest Sea Island with annexations starting in1970s;
4. Johns Island → the second largest island on the east coast with only a small, concentrated portion annexed into the City limits starting in the 1980s; and
5. The Cainhoy Peninsula → linked to the City via the Mark Clark Expressway through Daniel Island, its large scale annexations began in 1990s and continue today.

Figure 3.3, Charleston five distinct land masses

3.1.2. History of the site and the old city boundary

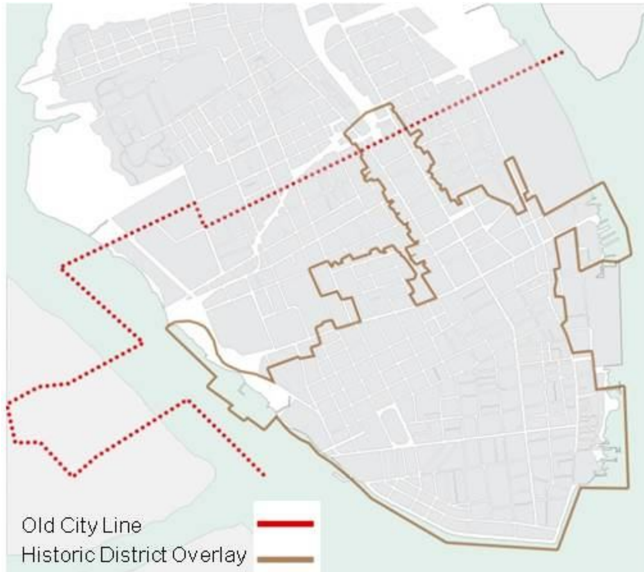


Figure 3.4, Old city boundary

The City of Charleston enjoys its place at the center of a diverse and storied region that typifies what is meant by the Low country. Encompassing a vast array of preserved forests, marshlands and meandering rivers, stunningly beautiful beaches, historic plantation properties, charming agrarian communities, and diverse towns and cities, the Charleston Region is abundant with some of our nation's best examples of historic sites, cultural offerings, regional craft, cuisine, and architecture. Not surprisingly, Charleston is the fastest growing city in South Carolina, as visitors from across the country have succumbed to its charms to settle here, and its urban area is the most populous in the state.

Much of Charleston's historical importance and wealth was derived from its position as a "great port town," as its Lord Proprietor, Anthony Ashley-Cooper, destined it to become. Charles Towne soon became a bustling center of trade and commerce as the fourth largest port in the colonies, after Boston, New York, and Philadelphia. And still today, Port activity is second only to tourism as the leading source of revenue for Charleston.

3.1.2.1. Peninsula

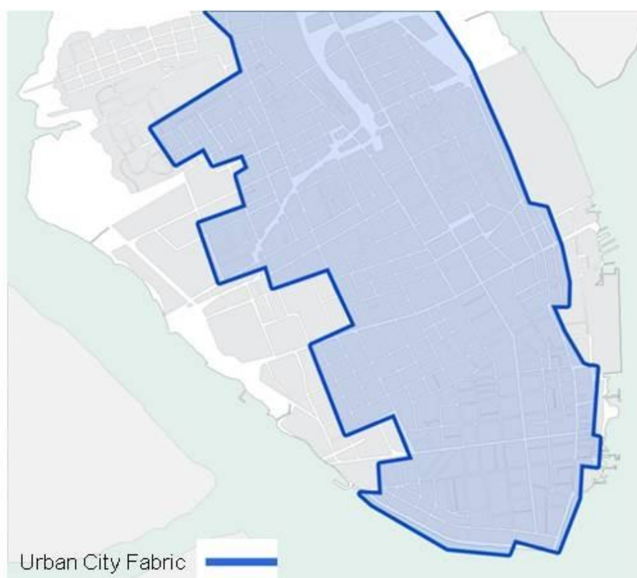


Figure 3.5, urban city fabric

The Charleston Peninsula is formed by the confluence of the Ashley and the Cooper Rivers. Charles Towne was founded in 1670 on the west bank of the Ashley River, but soon moved to its present location along the Cooper River. A walled city arose on higher ground along the shoreline with its waterfront dominated by the port. Today, much of the original peninsula is skirted by lower land created from landfill. A chronological inspection of historic maps of Charleston illustrates an ongoing outward growth of the city's shoreline into areas formerly marsh, mud, or even water. As a result, much of Charleston's historic urban fabric is upland of its waterfront, with the exception of the Battery. Waterfront land is often held in large tracts of ownership, either by the city, the state, or by institutions, typically limiting or precluding access by the public.

3.1.2.2. Urban Growth: Surround the City with Green

In order to protect the natural environment and preserve the unique quality of each area, urban growth should be managed. This means urban and suburban development should not spread throughout rural areas and nature should be protected in suburban and urban sections of the City.

3.1.2.3. Urban Growth Boundary

In the City's 2009 Resident Survey, 91% of respondents agreed with limiting urban expansion of the City. Over ten years after the creation of the Urban Growth Boundary, strong support still exists to limit urban development. In fact, in Charleston County' s 2008 Comprehensive Plan Update, they stated that the Urban Growth Boundary needs to be institutionalized through intergovernmental agreements and/or working relationships in order to direct higher intensity growth to the Urban/Suburban area where adequate infrastructure and services are in place, allowing for preservation of rural character of the majority of the County."

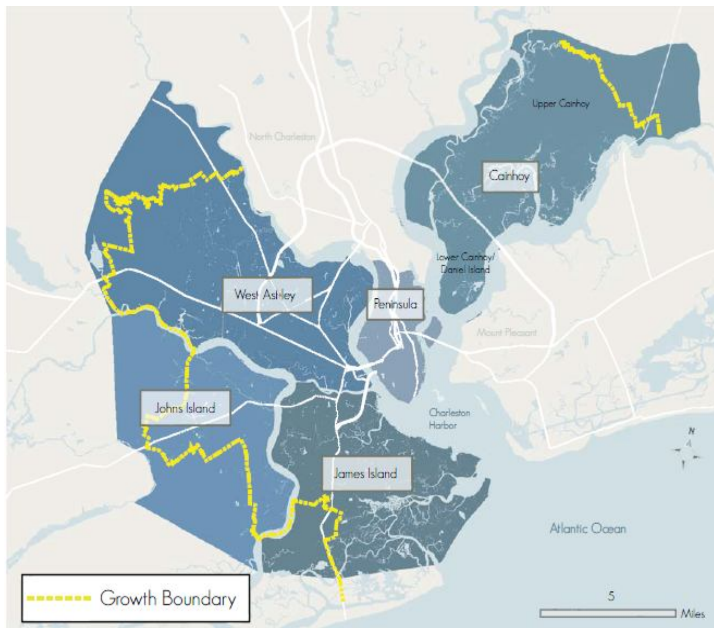


Figure 3.6, City line and urban growth boundary

Accordingly, the 2008 Charleston County Plan designates areas of the County for urban/suburban and rural development patterns. These recommendations affect City growth in West Ashley, James Island, and Johns Island. It should be noted that in this and previous planning documents, the City of Charleston supports the original location of the Charleston County Suburban/Rural lines on James island, thereby keeping a large portion of the southwest quadrant of James Island outside the UGB (south of Grimball Road and west of Old Military Road). Areas outside the UGB are hence designated only for rural development levels. However, Charleston County removed their UGB designation from James Island completely in 2004.

As there has been continued public support to control and limit development, making the location of the UGB of critical importance. Therefore in 2007, the Century V Plan was amended to include criteria for adjusting the UGB. These criteria require that justifications be made to warrant an adjustment in the boundary, including evidence the new location of the UGB would: 1) better protect the public interest, 2) better preserve of rural character of lands beyond the UGB, and 3) better secure the line as a permanent fixture (i.e. the land outside the UGB becomes publicly owned making it more than just a political marker and contributing to a permanent greenbelt system).

In 2008, the Long Savannah development utilized these criteria in moving the UGB in West Ashley to accommodate that development's plan. One of the key benefits of the move was the creation/preservation of Charleston County's largest park just outside the new UGB, and a City park on Bear Swamp Road. These parks contribute to the City' s plans to surround the City' s edge with green spaces and essentially encircle Long Savannah making the UGB more permanent in this location.

An additional alteration to the UGB is to bring it in closer to the existing urbanized areas along outer Ashley River Road.

3.1.2.3. Urban Growth Goals

Develop and maintain a sufficient open space/parks system so that the City is diverse in uses and opportunities and includes natural spaces and wildlife habitat, as well as passive and active recreation with an equitable distribution of parks, trees and pathways throughout the community. Implement land use and transportation planning and policies to create compact, mixed-use projects, forming gathering places and sites designed to maximize affordable housing and encourage walking, bicycling and the use of existing and future public transit systems are the goals of the urban growth of Charleston city.

Figure 3.7, proposed changes to protected areas, including historic districts expansions and conservation districts creations.

3.1.2.4. Historic Waterfront

The rich and varied history of Charleston has been significantly shaped by the history of its harbor and its port. All maps and written accounts attest to this maritime focus. The Peninsula's eastern marshy shore, where land and water meet, was from the start a place of great and constantly changing activity which involved many of the city' s most prominent names. Here wharves, piers, landings, storage areas, and warehouses vied for a waterfront site in which to load, unload, and process. The trade in indigo, rice, cotton, and naval stores as well as slaves account for much of the city' s wealth, which over time resulted in the creation of some of our country's most beautiful public and private buildings, from churches and courthouses to private houses and gardens. This sophisticated urban setting became Charleston's hallmark. The working waterfront remained a driving commercial force which required continuous change in order to meet new needs, ship and cargo types, and required equipment from the 17th century to now. Oddly in a city which became obsessed with the history and preservation of old buildings, there was little interest in saving what was built on the waterfront. That was a place that had to do with business, where change was necessary to economic survival. The city's monopoly board had to be redone to continue to play the game of maritime money. At one time or another, what was land had become water and vice versa to this end. The only sure thing was that the waterfront remained a place of commerce and activity which continued to help support the city.

Figure 3.8, Mosquito fleet daily landing

Figure 3.9, Public landing, early 20th

Today the Union Pier is due to have yet another change in its character, one which combines a new cruise ship terminal with real estate development and public access to the waterfront giving the city a new and valuable relationship to its history-making harbor. At the eastern end of Market Street, the granite lined landing on axis with the Custom House, now covered over with a parking lot, will be restored. The city will regain its formal front door to the ocean - a long overdue acknowledgement of the port's role in Charleston's ongoing success.

3.1.3. Land use

3.1.3.1. Existing Land Use

Foster the sustainable growth of the City through encouraging infill, redevelopment, diverse, walk able neighborhoods and park spaces, well located mixed-use centers, and protection for our surrounding natural and rural areas are the land use goals.

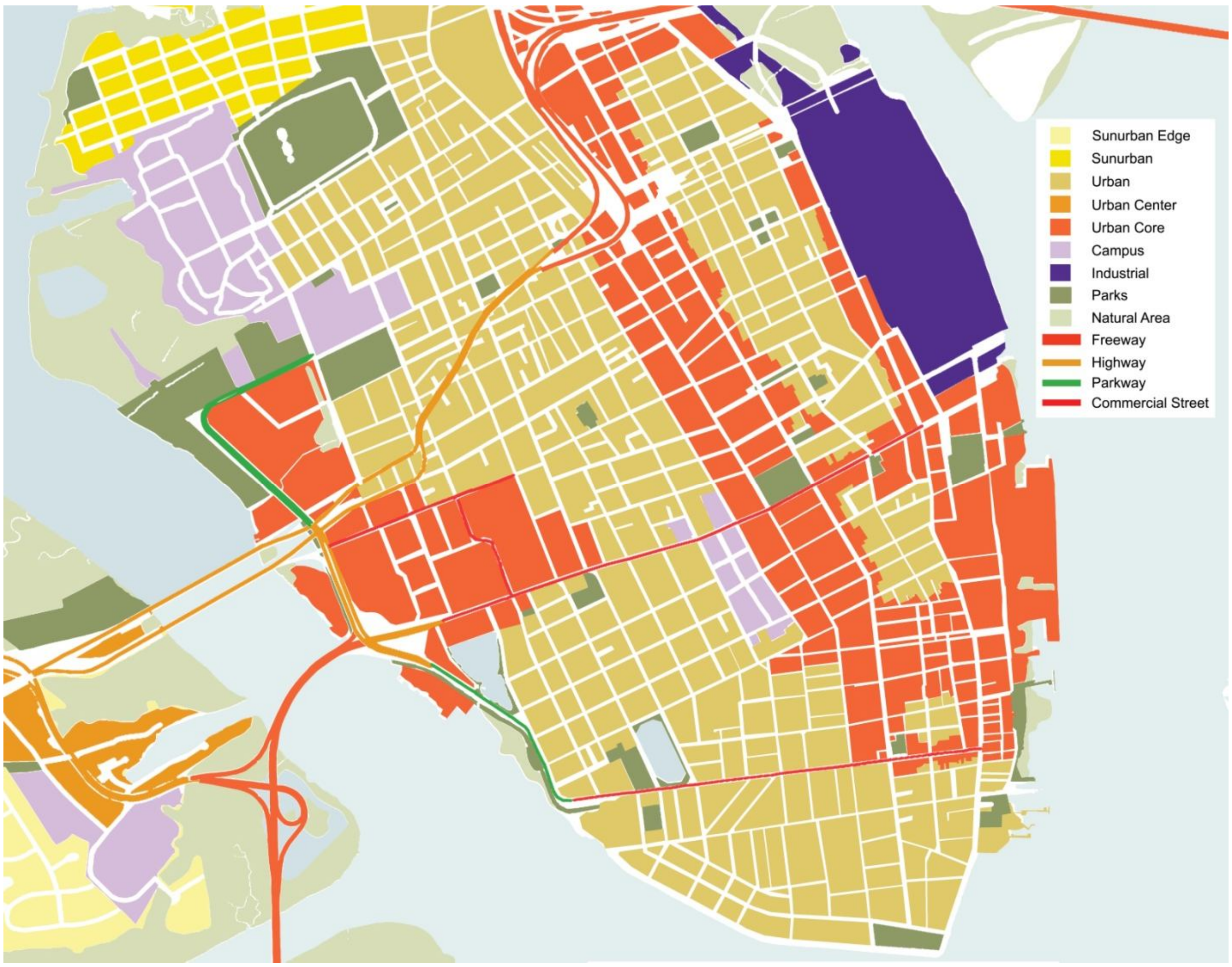


Figure 3.10, land use

An analysis of Charleston County Assessor's data and existing City of Charleston zoning coverage gives a good sense of how land is being used on the Peninsula, West Ashley, James Island, and Johns Island. Nearly 20% of the land on the Peninsula is categorized as commercial use, signifying it as the City's business center. However, currently a large amount of commercial space is vacant (15%), which gives rise to concerns that there is not as much business activity as could be accommodated. Nearly 30% of the Peninsula's zoned land is Heavy Industrial, tracing back to the area's industrial past. Conversion of many portions of this land seems likely.

3.1.3.2. Land Use Analysis (Buildings and points of importance)

Important functions used in analyzing the design area are shown in Figure 9. As it is shown, some functions which play an important role in the selection of our design area are located in a zone close to the waterfront walkway (Figure 10).

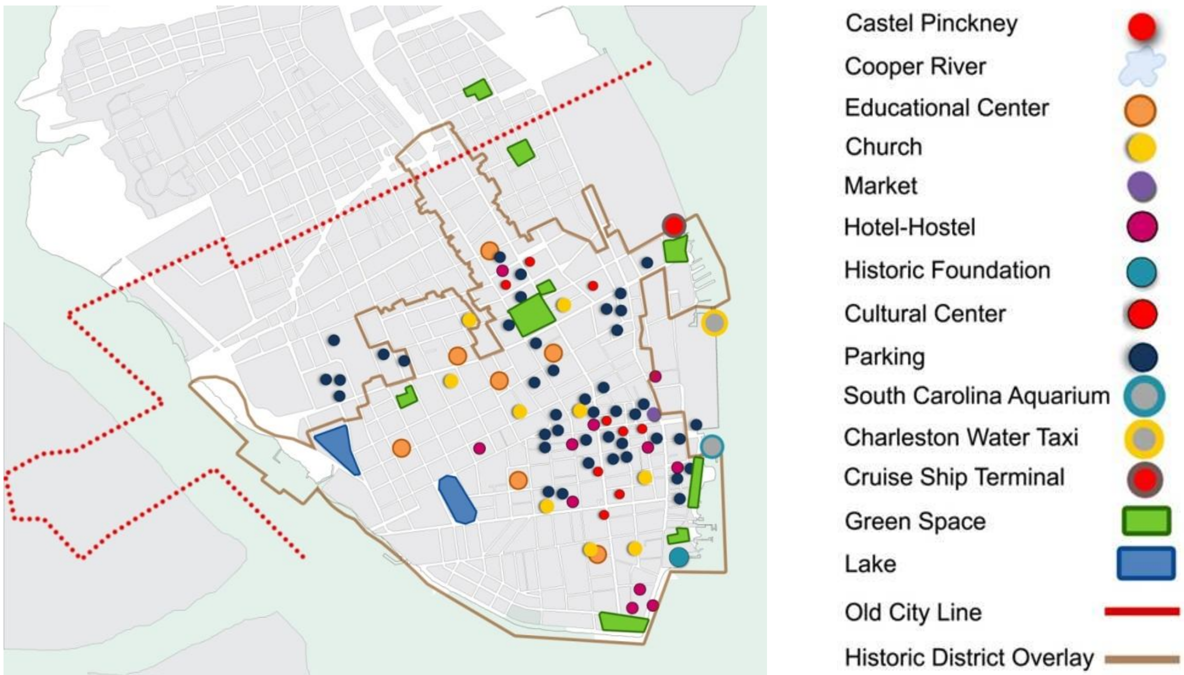


Figure 3.11, Functions affecting the selection of the design area

Most of the parking areas and cultural centers are situating in a zone which not only are close to waterfront walkway but also well-accessible for tourists. Being close and well-accessible parking would ease reaching the waterfront walkway areas. This factor has been taken into consideration on selecting design area along the walkway.

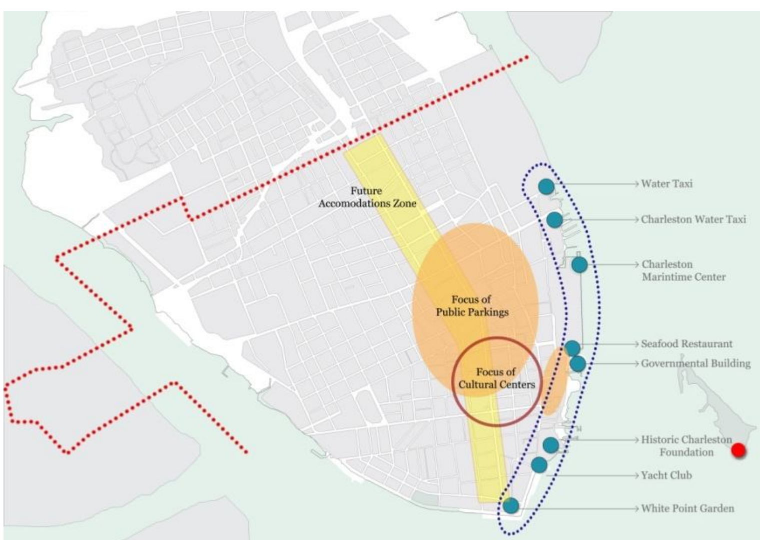


Figure 3.12, Functions analysis

3.1.4. Mobility

In the City of Charleston, mobility is not just a matter of moving cars from here to there. Charleston's unique geography of waterways and marshes separating the City's five land bodies limits the ability to fully connect various points of the City and region by roadway.

3.1.4.1. Water Transportation

Given the limited number of roadway connections to the peninsula, Charleston's geography makes water taxi and ferry services a unique mobility choice. Existing water taxi service available between the Peninsula and Mount Pleasant should be enhanced with better and more convenient dock locations downtown. Connections between the Peninsula and Daniel Island and James Island are viable in the short and long term and should be explored to a greater extent. This connection may become possible with a design of a new dock somewhere along the waterfront walkway area.

At one time, arrival by boat was the primary access to Charleston. Today, it is largely a drive-to destination and is well served by a network of interstate and US highways that form a framework around the region. Interstate 26 and US Highway 17 intersect at the Peninsula and connect the region to Interstate 95 to the north and west. Interstate 526 forms a loop around the urban center, connecting West Ashley, North Charleston, Daniel Island, and Mount Pleasant. Visitors by automobile often begin their tour of Charleston at the Visitor Reception and Transportation Center (VRTC), once an historic rail shed, where they can learn about the city' s history and board motor coaches to tour the city' s many attractions. Often the first impression for a visitor, Charleston's VRTC employs an architecture that is reflective of the history and richness of this great port city. The VRTC also serves as a venue for events attended by residents of the city. (Figure 13)

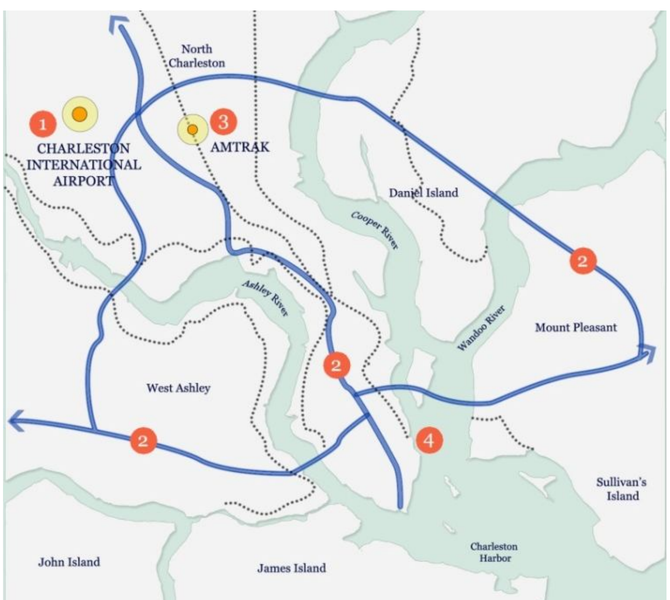


Figure 3.13, Access (points of arrival: 1- Plane: airport. 2- Car: highways/VTRC. 3- Train: Amtrak. 4- Boat: Union Pier)

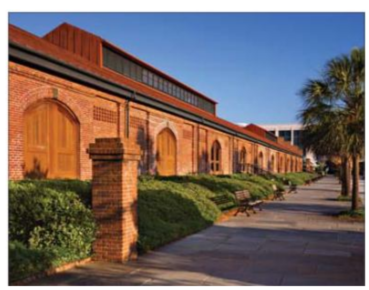


Figure 3.14, VTRC

3.1.4.2. Road Networks

Charleston International Airport serves the region's air traffic and is the state's busiest passenger airport. The region is also served by rail with an Amtrak station located in North Charleston. Charleston Station is served by trains that complete routes from New York to Savannah and New York to Miami.

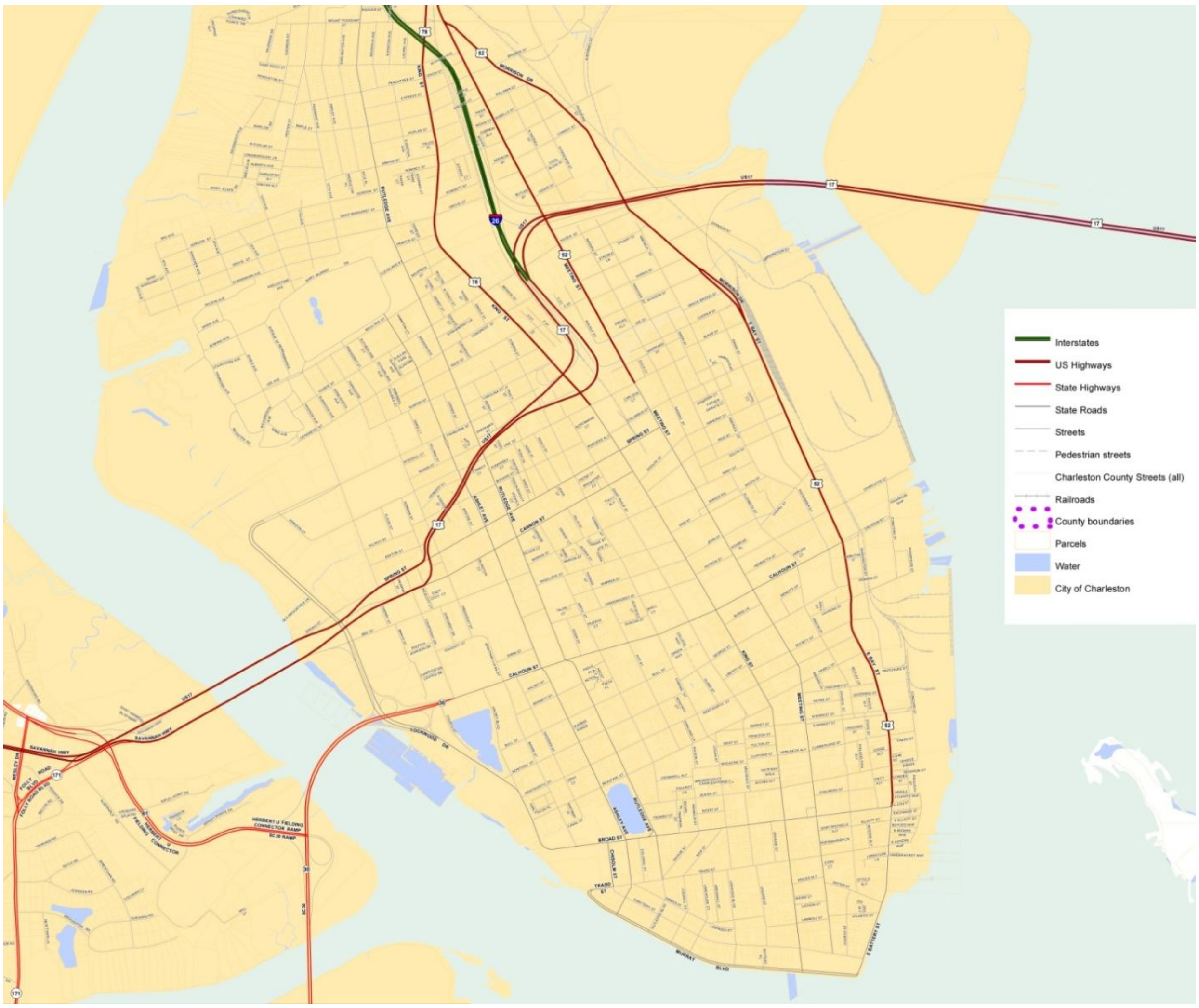


Figure 3.15, Peninsula road networks

Figure 16 shows how the traffic load has been changed after 10 years from 1998. There has been a reduction in traffic load of the streets located on the east part of the peninsula and in an area closer to the waterfront walkway.

Figure 3.16, Traffic counts

Another categorization of the streets is shown in figure 17. Primary roads (red dotted lines), secondary roads (orange dotted line), primary local access (blue dotted lines), secondary local access (yellow dotted lines) and seaways towards Fort Sumter (green dotted lines).

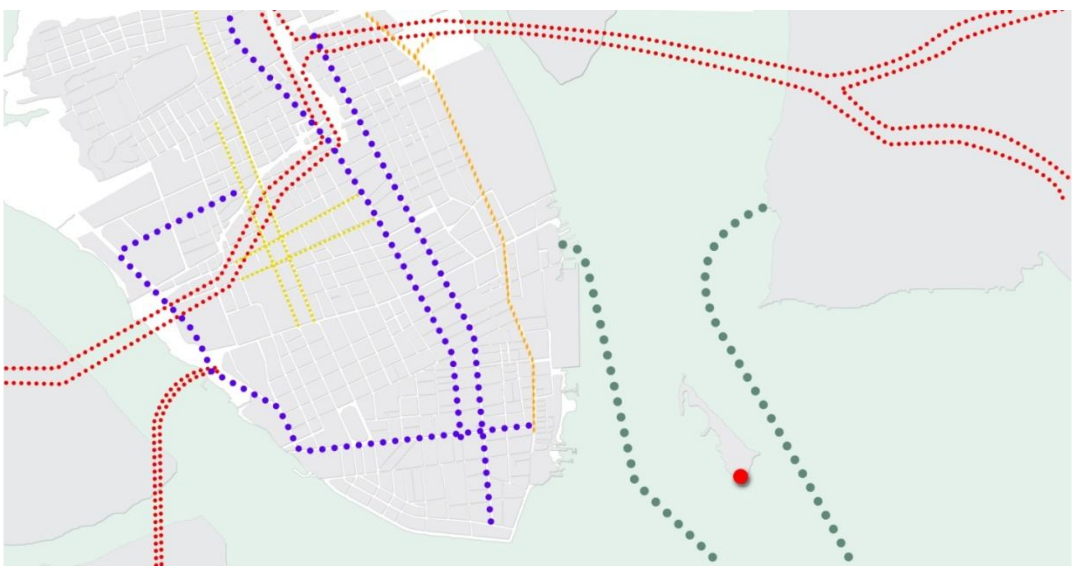


Figure 3.17, Street types

Charleston's Cruise Terminal is also one of the many ways tourists arrive in Charleston. As a port of call, tourists from other locales are offered the opportunity to explore Charleston's sites and enjoy its offering from their cruise ship as a home base. Home port ships, on the other hand, begin and end their voyage at Charleston's Terminal.

The building of a *New Cruise Terminal* in Charleston will provide an opportunity, as at the VRTC, to create a setting that reflects the character of Charleston and the history of the Port. Also, as with the VRTC, many of Charleston's residents have expressed an interest in a new terminal that could serve as a venue for events and increase public access to the waterfront.

3.1.5. Cruise Terminal Design

Establishing a new cruise terminal in the industrial zone along the waterfront walkway (northern part of the peninsula) is one of the future development plans in Charleston city which is going to affect our design area.

In cruise terminal design process, the attempt was to use public input in addition to specifically defined goals of the project, as people want:

- a more attractive cruise terminal,
- more public access to the waterfront,
- additional uses for the Union Pier property,
- a plan to address traffic issues,
- a plan that is contextual.

Goals of the project are defined to:

- Create a financially viable plan including a new cruise terminal that is attractive and in keeping with the character of historic Charleston
- Comply with today's enhanced cruise security requirements
- Mitigate impacts on existing infrastructure and traffic
- Identify additional uses for the Union Pier property that bring enjoyment to Charlestonians and enhance the local economy
- Increase public access to Charleston's historic waterfront

3.1.5.1. Site (Existing Conditions)

The Union Pier Terminal site is roughly 74 acres in area, of which 43 acres are land, 20 acres are constructed deck over water, and 11 acres are portions of the Cooper River contained in the tax lot. The site is roughly 3,000′ long north-south and 1,300′ at its widest point. The constructed wharf is 2,470′ long.

Figures 3.18, 3.19, existing dock area dimension with aerial view of the site

The site has three primary uses today, which include the location of the SCSPA headquarters building, the Cruise Ship Terminal and its associated parking and service facilities, and a large roll-on/roll-off cargo operation. The majority of the site is dedicated to the roll-on/roll-off operation, currently serving the import and export of BMW motor vehicles. Over 680,000 SF of shed structures dot the terminal. Many of the sheds are served by multiple rail lines that cross the site.

Other buildings and uses on the site include a restaurant, Fleet Landing, which occupies a former Navy building built in 1942 at the foot of Cumberland Street, and the historic Bennett’s Rice Mill façade. Bennett’ s Rice Mill opened in 1845 during the heyday of South Carolina’ s rice production. In the early 20th century, the Bennett family sold the mill and it was eventually acquired by the SCSPA in 1958. Nearly destroyed by a hurricane in 1960, the façade is supported today by a steel frame and surrounded by a fence. Through agreements with the SCSPA, local preservationist groups have assumed the stewardship of the façade.

3.1.5.2. Concept Plan

While the deck constructed over the Cooper River is essential for water-dependent uses, such as port cargo operations and cruise terminal operations, its role with respect to future uses at Union Pier was studied and considered carefully by the Concept Plan team. Even though the 1996 Concept Master Plan for Union Pier Terminal called the deck "an irreplaceable infrastructure resource," it raised questions of the insurability of non water-dependent structures that might be built atop the deck. Nor did the earlier plan consider the repair and upgrade to seismic standards required of the deck or the uncertainty of permitting uses in a critical area.

Figure 3.20, Concept plan- an illustrative concept

Upon consideration of these and other issues related to the deck, the Concept Plan team recommends the phased redevelopment of 8.4 acres of deck not required for the cruise terminal operations. In redeveloping this structure, a new waterfront on existing shoreline is revealed. Reversing man's effort to push Charleston's shoreline further into the Cooper River over the last several centuries, this Concept Plan invites the river back to the land.

Perhaps the most important opportunity the redevelopment of the deck affords is the opportunity to restore the historic wharves at the foot of the Custom House, once known as the Public Landing, and create a terminus to Market Street befitting its context and historical importance. Charleston's 1999 Downtown Plan identified this location as one of a number of "nodes" across the Peninsula in need of a focal point. Certainly the restored Custom House Wharves, with their massive granite bulkheads, will serve as a node for the city and for this area.

Figure 3.21, cruise terminal site

Figure 3.22, conceptual illustration

Figure 3.23, conceptual illustration

3.1.6. Peninsula Edges and Water Views

As a result of historic patterns of development and land accretion, the edges of the Peninsula vary from natural marsh edges, typically north of US 17, to urban edges along the Battery and along newer waterfront developments, to industrial edges in the areas controlled by the Port, notably Union Pier Terminal and the Columbus Street Terminal.

As a consequence of these edge conditions, waterfront views are either facilitated by street corridors and opens spaces, as along the Battery and in areas north of the historic district along marsh edges, or restricted or precluded by larger users, such as the Port terminals and the MUSC campus.




Figures 3.24, 3.25, 3.26, 3.27, Charleston's natural edge – Charleston's urban edge – Charleston's urban edge at Waterfront Park – Charleston's industrial edge at Union Pier.

Figure 3.28, Peninsula edges

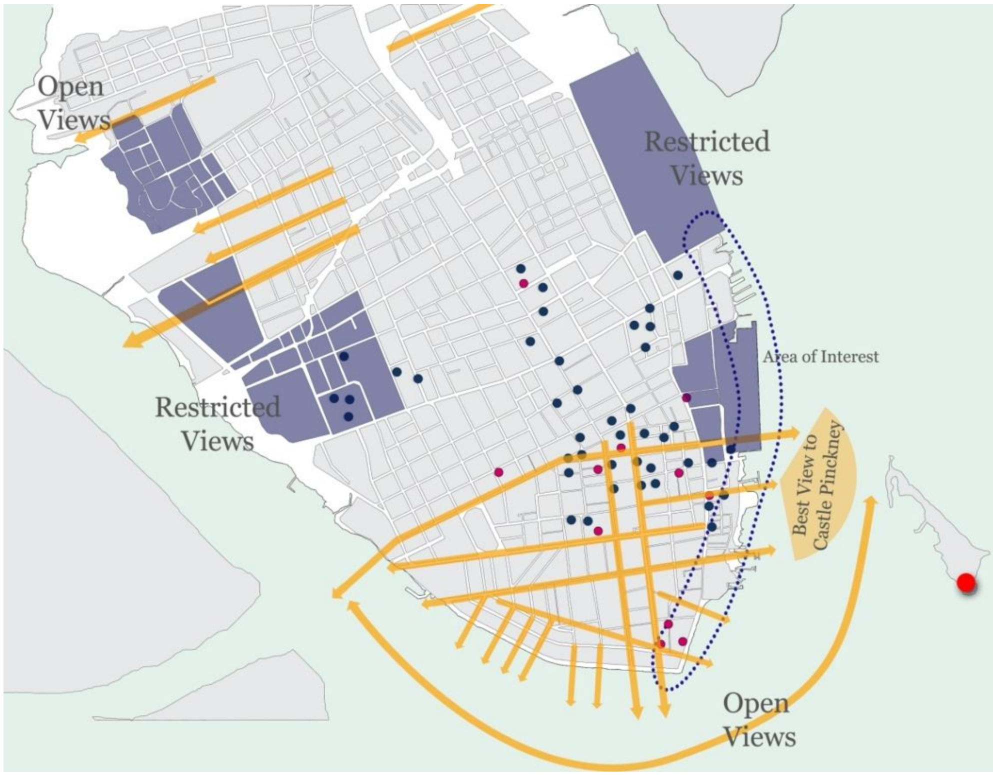


Figure 3.29, Streets visual accessibility analysis

Figure 3.30, analyzing the streets with a direct access to the waterfront

3.1.7. SWOT Analysis

Based on the analysis created from the study of the area a SWOT analysis matrix is created. Moreover, figure 27 depicts the SWOT analysis matrix in a graphical way.

Strength:

- Views of waterfront towards water,
- Long waterfront walkway,
- Proximity to touristic parts of Charleston,
- Easily accessible from Charleston surrounding lands,
- Historical attraction (both for Charleston and the Castle),
- Marin attraction around (South Carolina Aquarium),
- Wildlife attraction around (dolphins, pelicans),
- Already existing touristic ferry tours (castle Sumter),
- Mild winter weather,
- Proximity to New Cruise Terminal.

Weaknesses:

- Castle is unknown to the Charleston habitats,
- Biological attack to the castle,
- No deck on Shute s Folly Island,
- Low lying-marshy island,
- Soil weakness of the island,
- Covered with dense low growth,
- Climate change,
- Charleston is prone to hurricanes and the problem of high tide, rise in sea level,
- Land shifting problem,
- High humidity,
- Damages of the castle and the earth inside.

Opportunities:

- Adding a tourist attraction to Charleston city,
- Creating nightlife entertainment and harbor vitality in Charleston fabric,
- Increasing job opportunity,
- Making castle Pinckney as a landmark for South Carolina,
- Creating activities like market, temporary exhibition water sport,
- Creating bilateral connection between castle Pinckney and city.

Threats:

- Forced migration of pelicans,
- Gradual disappearance of the castle Pinckney,
- Propagation of the castle damages,
- Degradation of the environment.

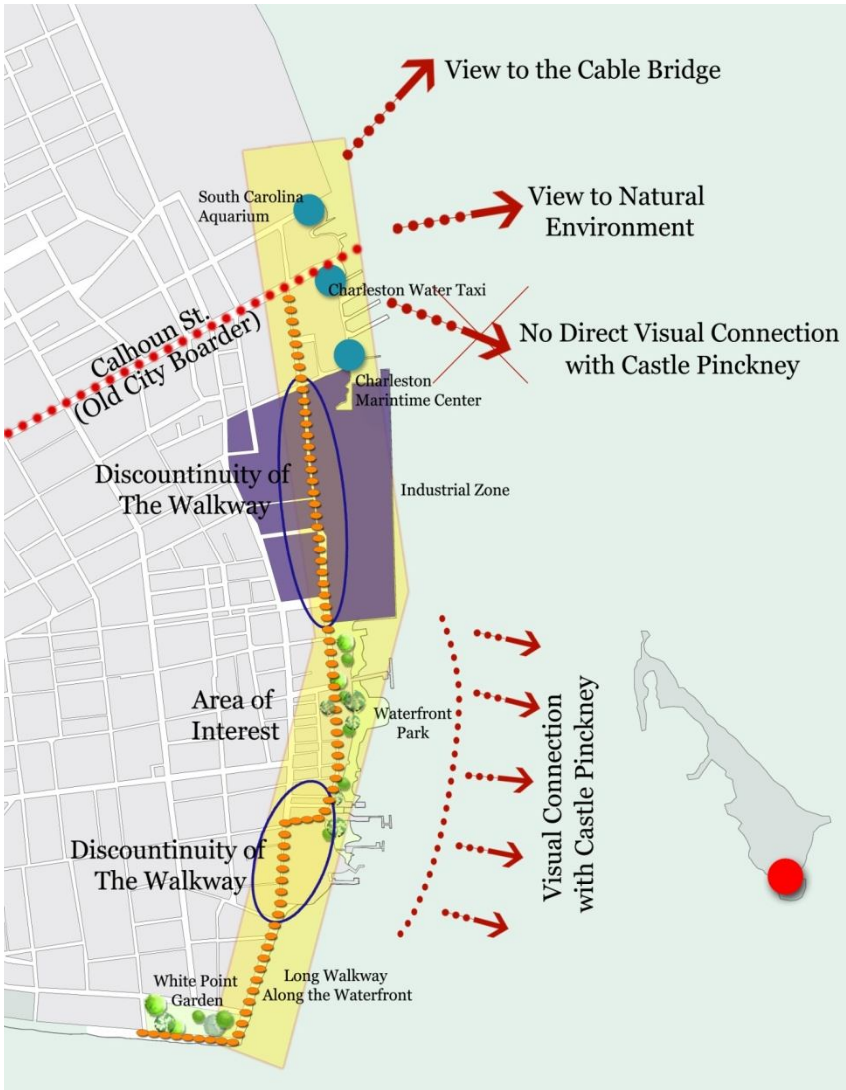


Figure 3.31, SWOT analysis map

Figure 3.32, Boat station

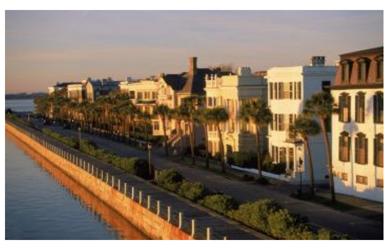


Figure 3.33, Waterfront walkway

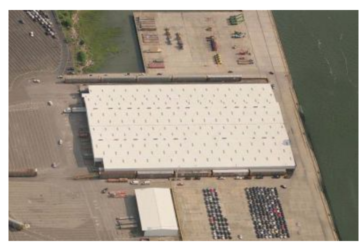


Figure 3.34, Industrial area

3.2. Defining the Area of Intervention

Having done the analysis including SOWT, we came to the idea of re-organizing the waterfront walkway by defining a starting and an ending point along the walkway, while they are the South Carolina aquarium and the White Garden Park respectively. So, along this pathway which is recognized as "area of interest" by us, the main goal is to deal with its discontinuity. Moreover, a third point between these two main points is defined. This is the pier with a good visual connection to the Castle Pinckney.

Our idea was to take advantage of the location of this pier and refurbish the area in order to take one step ahead towards the goal of the completion and our project. The so-called pier, despite its notable location, is not crowded enough. People just come to the fountain at the entrance of the pier, then they may refuse coming further because the lack of attractive points. Those reasons led us to set this pier as our aim.

To achieve this, we focus on the pier which is located right at the end of the street with a good accessibility and open view to the waterfront walkway shown in figure 26.

3.3. Proposal Concept:

Dividing function into two;

1. **On the waterfront**

- History of castle showing its shape alternation
- Explaining different functions through history

As there are ample of documents about the castle, we proposed to provide a permanent exhibition exposing these documents to show the history of the city and Castle Pinckney, in addition to show its different physical shapes during the history. It helps us to provide our welcome center on this pier, within this open air exhibition, the ticket area as in the competition brief is mentioned about so that there is no need of many staffs.

We also proposed to build a small restaurant to serve the typical foods of Charleston which need no preparation work a lot at the second level of the pier (as shown in the picture below), with orientation towards the Castle Pinckney.

In addition, our idea is to make this restaurant transparent in order to take advantage of the surrounding views. In this case it can be also used as a part of our Belvedere.

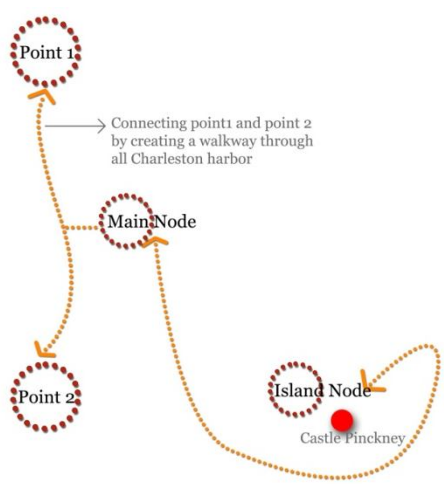


Figure 3.35, Concept plan diagram

2. **On the island**

- Visiting archeological site
- Having a panorama view of surrounding through the casements

3.3.1. Goals

- **Reviving the forgotten castle**, introducing it to the people of Charleston and the tourists.
- Adding more value to the Water front park.
- Developing touristic aspect of Charleston by adding a touristic **gathering node** and **touristic attraction**.
- Considering the **visual connections** between city and castle.
- **Connecting** the castle Pinckney with **other forts**.
- Respecting to the **sky line** of the city and tower of the churches.
- Respecting the **nature**, environment, wildlife (pelicans, dolphins), and history besides each other.
- Providing **educational opportunities** for local people in order to improve social awareness.
- Developing Charleston's **economy** and creating job opportunities for citizens.
- Considering **sustainability** for our project in three aspect: economy, society, and environment.

The issues we should take into consideration for the Castle Pinckney:

To allocate a new function to the Castle Pinckney, we took into consideration some issues which we should deal with while we were working on this project.

3. Wildlife and natural habitats
4. Existing physical condition of the castle
5. Need of the regular maintenance
6. Sustainability

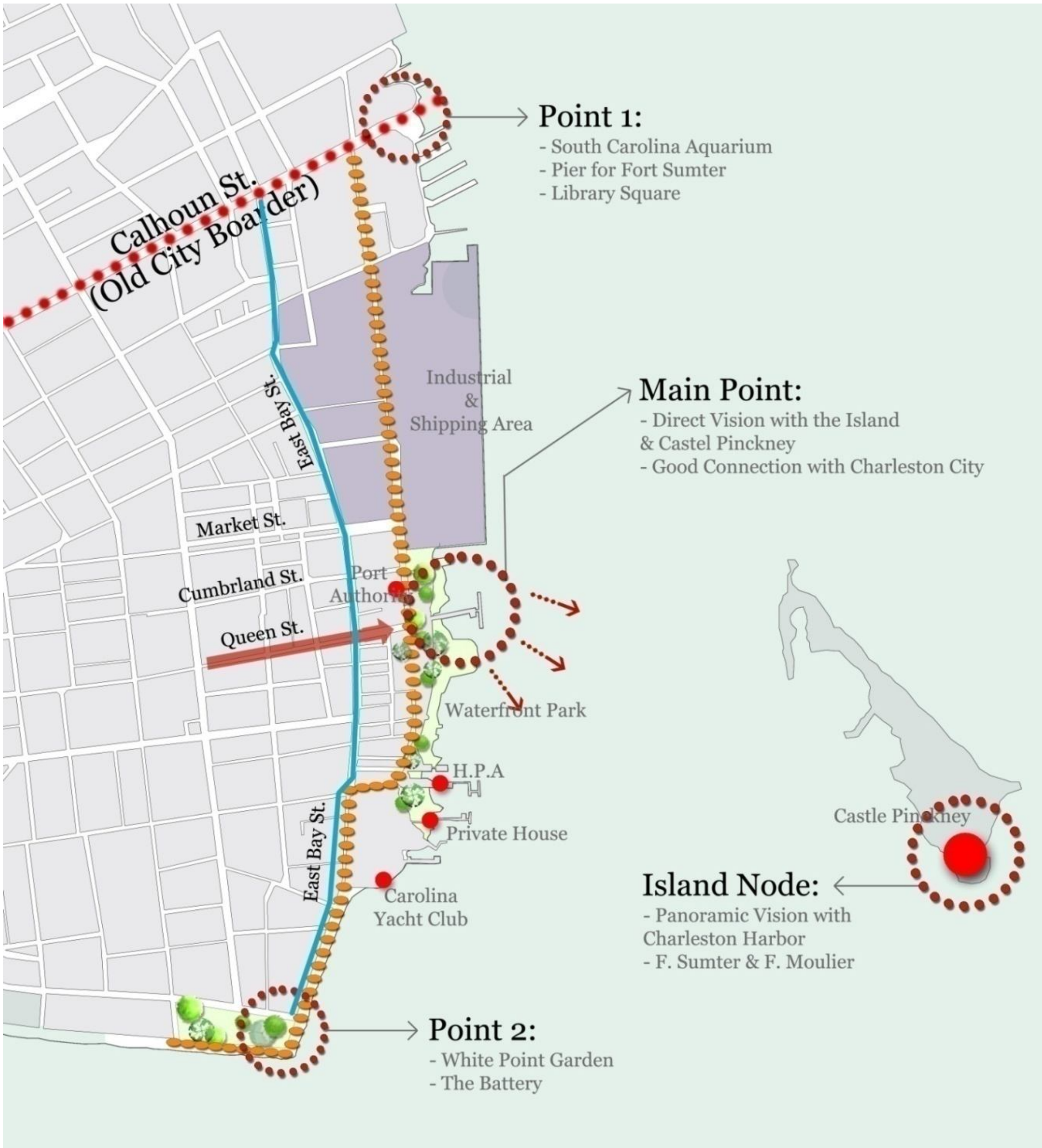


Figure 3.36, Concept plan map

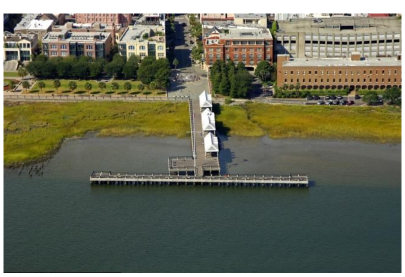


Figure 3.37, Main point

Figure 3.38, Point 1

Figure 3.39, Point 2

3.4. Master plan

Our master plan is based on providing a continuous walkway by creating:

– Connecting two points (White Point Garden and Charleston Aquarium) by continuous bike/pedestrian lanes.

– A refurbished main pier including a restaurant and welcome center at its end.

– Considering special areas as “special initiatives”.

– Bringing the shoreline to visitors.

Figure 3.40, Master plan

3.4.1. Special Initiatives

There are four special initiatives, or special areas, within the Concept Plan (shown in figure 39). Each initiative is tied to the past, present, and the future of the working waterfront and therefore inextricably linked to industry and the residents of Charleston. The four special initiatives of the Concept Plan are:

- Restoration of historic public landing
- Restoration of the natural shoreline

- Restoration of Bennett's Rice Mill and Creation of Rice Mill Park
- Creation of Pavilion for the History of the Waterfront in Union Pier Park

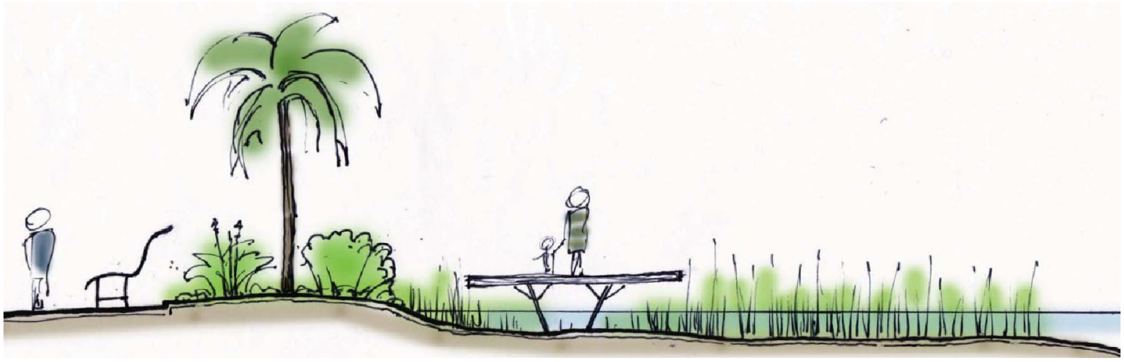


Figure 3.41, Illustrative section showing transition through marginal zone at shoreline

3.4.1.1. Bringing the Shoreline to Visitors

Opportunities for public interaction exist throughout the restored shoreline area. For example, boardwalks raised above the marsh may carry pedestrians though the thriving intertidal community (as shown in the sketch below); place design may call attention to wildlife and natural patterns. Outlooks with good views of the restored marsh and other shore habitats can give visitors the chance to observe birds such as egrets, marsh wrens, and perhaps even seaside sparrows, which are found only in salt marsh grasses like cord grass.

A series of steps down into marsh habitat could lead the public into the ecological processes occurring on the waterfront.

The Plan proposes significant changes to the Charleston waterfront by removal of the structures (dismantled areas) that impeded natural processes in the harbor specifically the natural development and maintenance of salt marshes and other South Carolina aquatic habitats.

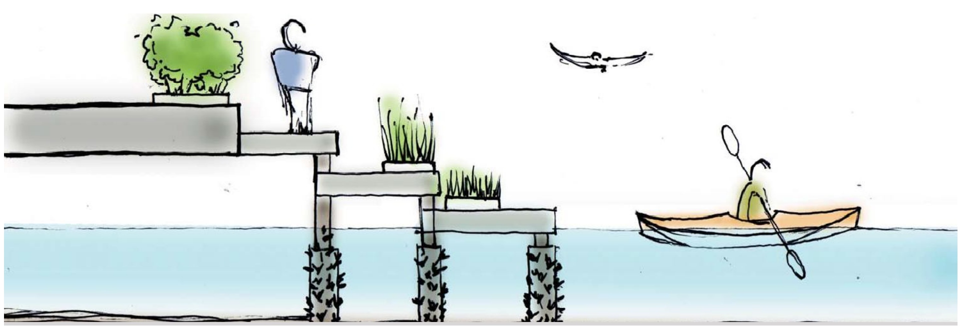


Figure 3.42, Illustrative section showing how to bring the shoreline to visitors

Figures 3.43, Master plan zoom-in

Chapter 4

Conservation

Chapter 4

Conservation of Castle Pinckney

Imbued with a message from the past, the historic monuments of generations of people remain to the present day as living witnesses of their age-old traditions. People are becoming more and more conscious of the unity of human values and regard ancient monuments as a common heritage. The common responsibility to safeguard them for future generations is recognized.

Castle Pinckney, the oldest surviving fortification, has been forgotten for ages and declines continuously. A reuse project of such old and monumental fort is not just a big and exciting challenge, but it also comes with great responsibility. For this reason a careful conservation study has been applied to the Castle according to available documents. The result is several solutions and suggestions for intervention to castle which are described later in this chapter.

4. Analyzing Castle:
4.1. Diagnosing and analyzing damages

As some documents including CAD files and photos captured by students were exists about the Castle Pinckney, our damage survey started from merging photos together, and superimposing on the CAD drawings in order to be able to show the materials and subsequently, the damages on each façade. The procedure facilitated generating damage map shown in following pages.
So, we started with depicting the materials on the CAD file merged with a related photo and the results were recognizing different materials which generally are:

1- Brick: Three different bricks were recognized on the building of the Castle Pinckney. First type comprising the major part of the façade and two other types which comprising less part of it shown as rough bricks.

2- White wash: It was recognized as a material added on the main façade during the history and it is not the original material.

3- Cement sealing: It can be seen in some parts of the facades where the sealing of the cracks were the purpose of the conservator or a person who has done it.

4- Metal: Upper parapets and the stairs on the west elevation are the only parts in metal.

5- Stucco or Mortar: A thin layer

6- Vegetation: Mostly the castle is covered by vegetation attack, in some part the root of trees cause decrease in load bearing capacity of the walls.

On the other hand, Castle Pinckney with its brick-masonry structure is facing several kinds of damages listing bellow:

- Surface growth and staining.
- Efflorescence (white powdery residue building up on the wall face).

- Whitewashing of the bricks in façade.
- Soft, loose or crumbling mortar.
- Spalling (deterioration of the surface of bricks).
- Loose bricks becoming dislodged.
- Cracks appearing through the bricks or Mortar mainly because of the pressure.
- Bulging or shifting out of, often indicates that the brick or stone masonry surface veneer is separating from the rest of the wall.
- Moisture penetration from a number of sources; including rising damp; rain; and in the form of evaporation followed by the crystallization of soluble salts.
- Local settlement under the foundation and walls in some parts.
- Metal corrosion.

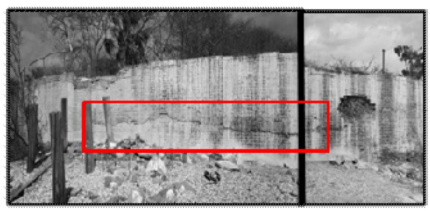


Figure 4.1, damage of the Castle, taken 10/01/2012

Figure 4.2, damage of the Castle, taken 05/03/2011

Figures 4.3, 4.4, 4.5, 4.6, spalling, settlement, crack and lost bricks are among severe damages

The State Ports Authority, which owns Castle Pinckney, figures the clearing work will serve several purposes. Clearing the brush will help the control of the bird nesting & populations on the island. The bricks of the wall particularly in southern part are pretty soaked in pelican droppings.

Figures 4.7, 4.8, 4.9, 4.10, bird nesting and pelican droppings on the southern part of the Castle

In some parts of the castle the bricks of the outer layer of the wall have been lost:

Figures 4.11, 4.12, 4.13, missing bricks of the outer layer of the walls

In the following pages geometrical survey, damage and material mapping is presented based on 4 elevations of castle Pinckney.

Figure 4.14, geometrical survey of the Castle, South elevation

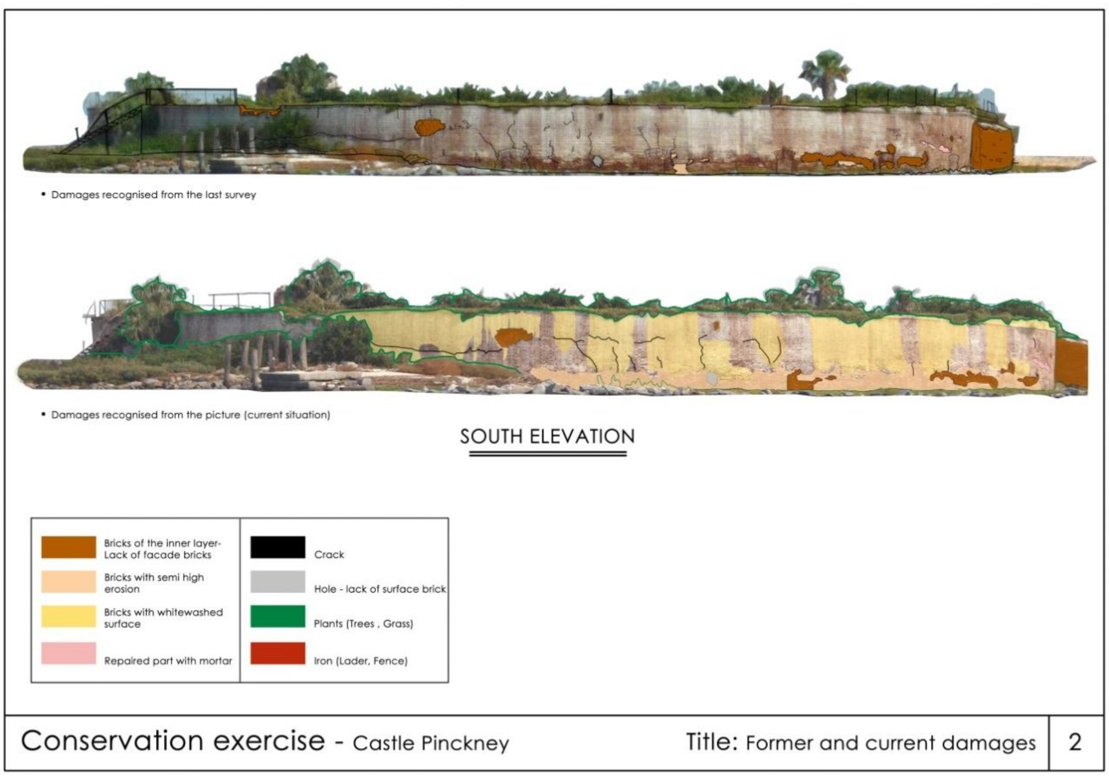


Figure 4.15, damages of the Castle, South elevation

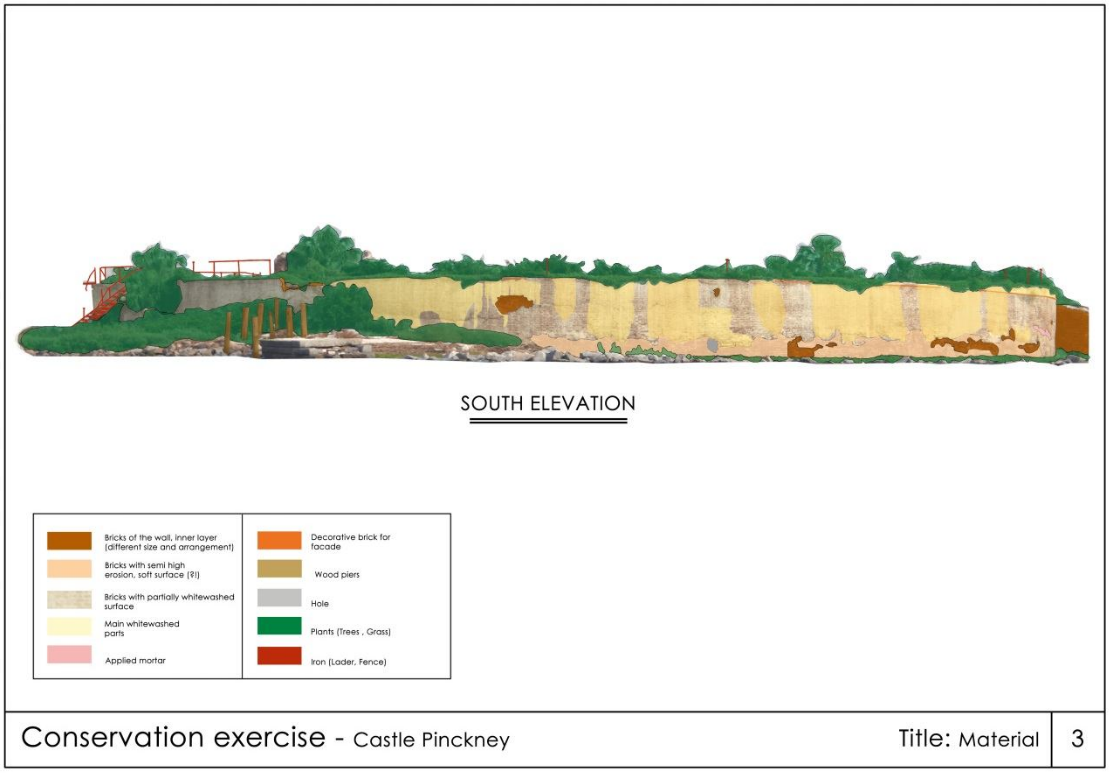


Figure 4.16, material of the Castle, south elevation

Figure 4.17, geometrical survey of the Castle, West elevation

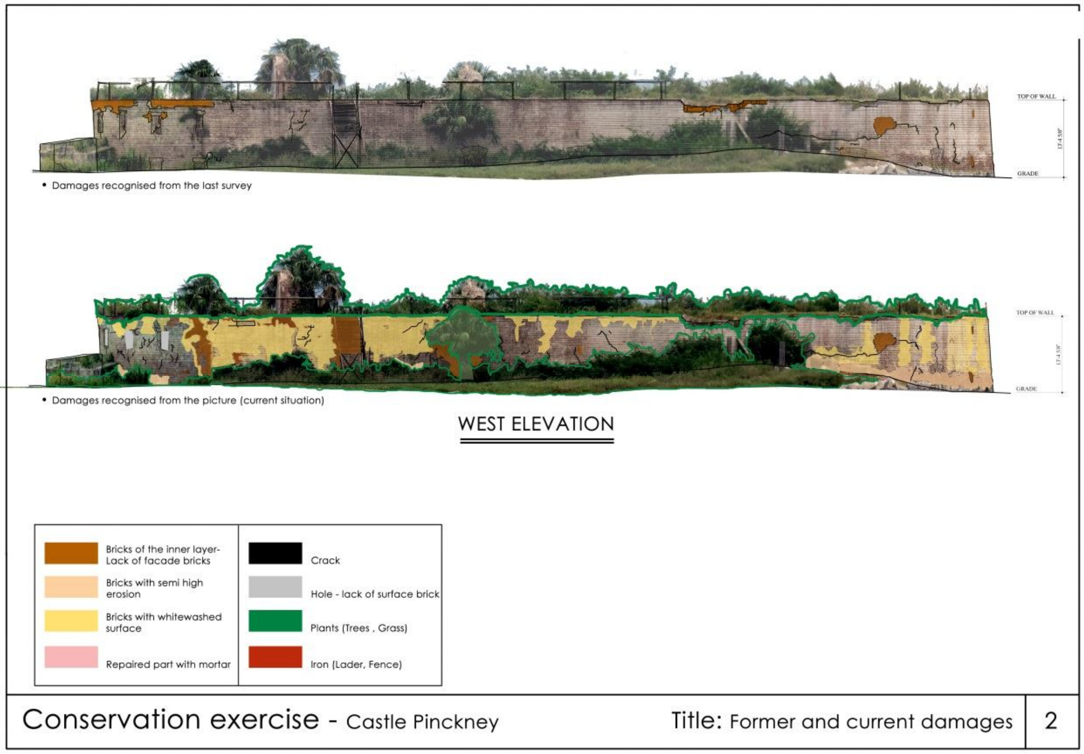


Figure 4.18, damages of the Castle, West elevation

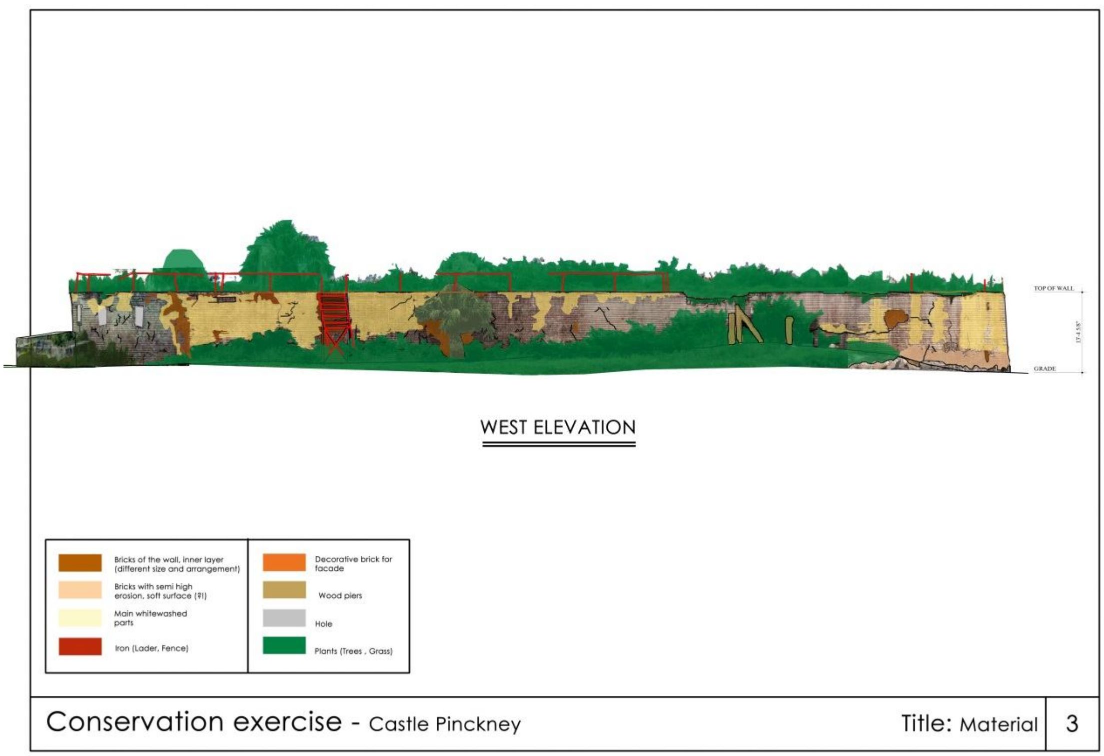


Figure 4.19, material of the Castle, West elevation

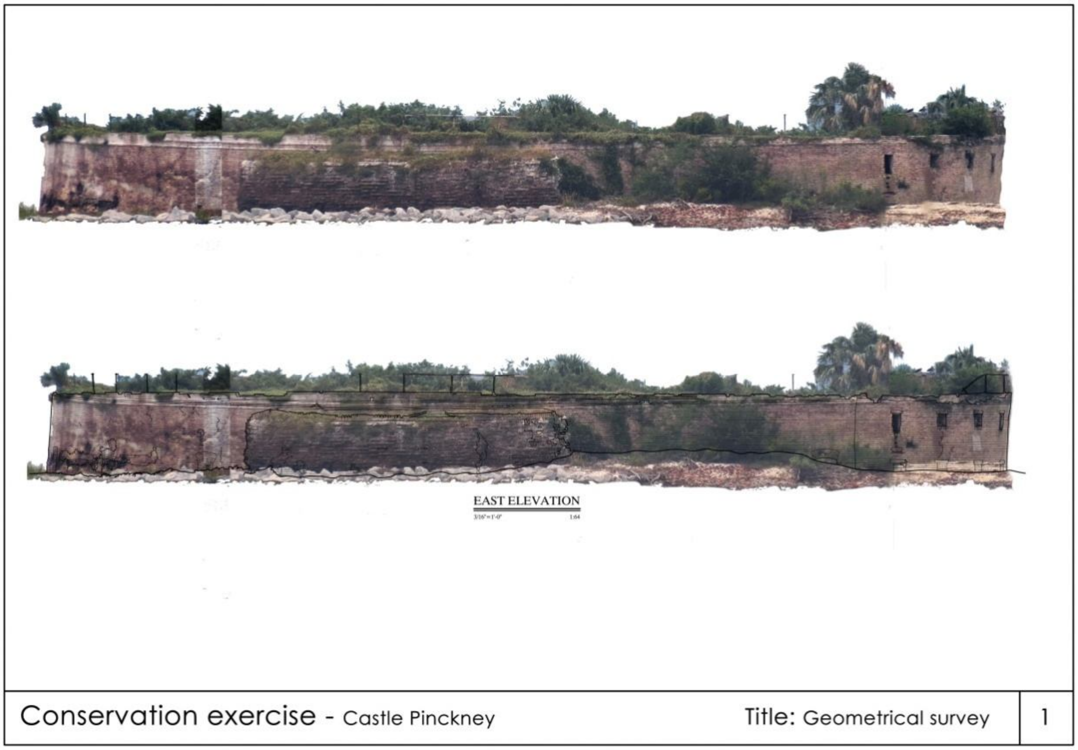


Figure 4.20, geometrical survey of the Castle, East elevation

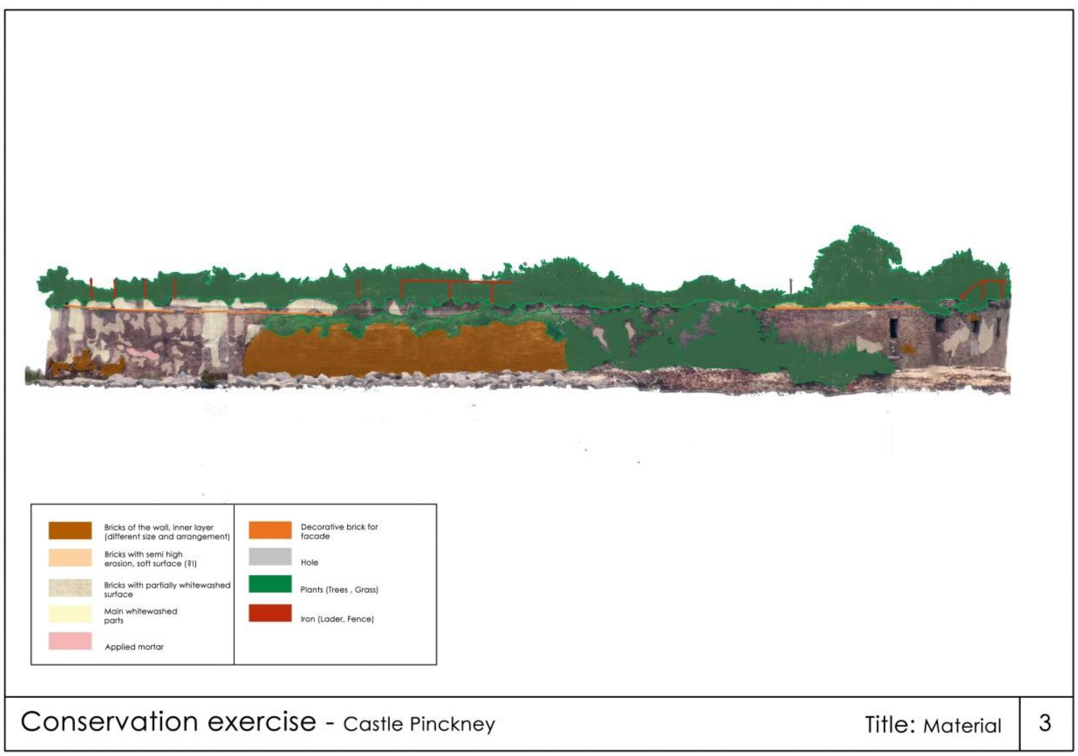


Figure 4.21, material of the Castle, East elevation

Figure 4.22, damages of the Castle, North elevation

Figure 4.23, material of the Castle, North elevation

4.2. Interventions

Conservation is the action taken to prevent decay. It embraces all acts that prolong the life of our cultural and natural heritage. The minimum effective action is always the best.

- Each intervention should, as far as possible, respect the original concept and construction techniques.
- The limitation of interventions at the minimum possible level, depending on the level of knowledge of the structure and on the use of appropriate investigations/monitoring techniques;
- Repair is always preferable to replacement.
- The removability of the interventions and the compatibility of traditional/modern/innovative materials and construction techniques.
- The basis conditions for compatibility is the respect of the building and the improvement of its values

4.2.1. Proposed repair and strengthening techniques

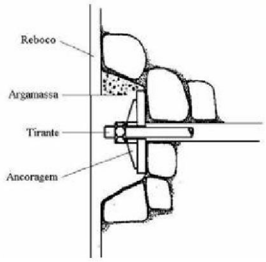
A wide variety of intervention techniques can be considered for strengthening and repair of masonry structure of the castle which is facing damages due to overload, ground settlement, wild nature attack like root of vegetation, wave impact. A rough distinction can be made among the traditional and the modern ones. Traditional techniques employ the materials and building processes used originally for the construction of ancient structures. Modern techniques aim at more efficient solutions using innovative materials and technologies. And also from the analysis carried out it seems that, it was pointed out that the most vulnerable element is the façade as the other part are buried under earth. So, we tried to focus mostly on the strengthening of external walls of castle. Bellow we list several suggested interventions strategies for Castle Pinckney.

4.2.1.1. Tie bars

In some part of castle we have seen the detachment of different leaf of masonry wall, and usually these parts of the wall are suffering from damage related to ductile failure. By applying this technique we can improve the overall structural behavior by ensuring seismic cooperation between structural elements.

Tie bars are used to restrain further outward movement of masonry walls. They consist of a bar passing through the full width of the bridge, with anchorage plates at each end, generally secured by a nut and washer, to provide the restraint to the wall.

One of the advantages of using tie bars is that they can be inserted with little or no disruption. However their effectiveness has never been scientifically proved and many engineers are worried that sections of the wall may fracture around the anchorage plates, the walls then becoming potentially unstable. There is no real guidance as to suitable spacing for tie bars. In one of the cases studied there appeared to have been further movement of a wall since installation of the tie bars. Rusting of the exposed parts, in one case severe, was also found. The use of stainless steel bars could be considered, or the application of Cathodic protection.






Figures 4.24, 4.25, 4.26, 4.27, using tie-bars for restraining the outward movements of the masonry walls of the Castle

4.2.1.2. Re-pointing

In surface mapping, it is seen that masonry walls presenting visibly deteriorated joints or mortar in poor conditions. In these cases re-pointing technique is used to restore the load bearing capacity of external leaf. It may also prevent the wall from deteriorating further to a point that requires more expensive repair work.

For this technique we need to avoid using the too soft mortar or a mortar that is too harder than the brick which can lead to cracking in masonry units among other incompatibility dysfunctions. It is important to select a mortar with compatible properties to the existing structure.

For proper re-pointing (cleaning and removing top surface) should first be done to a minimum depth of 15mm, however, 25mm is preferable. The depth should be uniform and square. Power tools should be avoided if they may cause more damage to the masonry work. Bucket handles or struck and weathered joints (Fig. 35) should be used for finishing as they contribute to brickwork durability because the tooling of the joints reduces the permeability of the mortar surface.


Figures 4.28, 4.29, poor condition of the joints and mortar in Castle Pinckney

4.2.1.3. Injections

In some parts of walls especially the external leaf of brick wall in castle Pinckney we can use injection technique to improve the strengthening action of the overall wall. Injections use grout to fill voids in the fill and backing, deeper than near-surface. The injection fill can increase load capacity by improving load distribution. It can also be a preventative measure to slow further deterioration of the structure. Injections will reduce the amount of water percolation through the structure. For installation, a matrix of holes is drilled into the structure, flushed with water to clear debris, and then injected with grout starting at the lowest point and working upwards. Grout is injected with a pressure grouting machine until the pressure limit is reached, until it appears at adjacent holes, or until a predetermined amount has been injected. Pressure should be kept to a minimum as not to cause internal damage to the bridge. After injection, the hole is plugged with a core from the drilling or other piece of brick or stone with similar appearance to the existing material.

If injection holes are properly plugged, the intervention will have no negative effects on the appearance. The costs of injections are similar to that of grouting but will incur additional costs in the amount of grout needed and additional equipment.

4.2.1.4. Near-Surface Reinforcement - Innovative FRP Techniques

In this technique, braided carbon fiber rope is used as the reinforcing material. The fiber rope is impregnated with an epoxy saturant immediately prior to installing in prepared paths. Pathways for the reinforcement are created by cutting straight grooves running vertically through head joints and brick units, and horizontally at bed joints. The grooves are cut as wide as the mortar joint thickness and to a depth of about 25 mm. After cleaning the grooves by compressed air, epoxy primer is applied. The grooves are then partially filled with an epoxy adhesive commonly used in gluing external FRP reinforcement to RC structures using a manual caulking gun. After installing the reinforcement, another layer of the epoxy adhesive is applied to fully encapsulate the FRP carbon fiber rope. To maintain appearance, re-pointing mortar, similar in color and properties to the existing mortar, is applied from the outside. Also grooves cut in brick units are filled with a matching mortar.

When cutting grooves through the brick units is not acceptable from a restoration viewpoint, holes are drilled through the units at head joint locations in alternating courses so that a fairly straight, but slightly “zigzagged”, vertical path is created. After cutting the alternating mortar head joints, 9.5 mm (3/8 in.) diameter holes are drilled through the brick using long bits. The use of long bits allows drilling to be nearly vertical. Alternatively, when the top of the wall is accessible, which is usually the case for façade walls, vertical near surface drilling can be done over the wall height similar to central coring. The impregnated carbon fiber rope is then inserted in the holes using steel pulling wires and embedded in epoxy-filled grooves cut through the mortar head joints to bond the reinforcement to the masonry wall.

Figure 4.30, near-surface reinforcement of the walls

4.2.1.5. External reinforcement

In the northern part of castle that we have 2 small curves in plan, we propose to strengthen the wall by using external steel belt in upper part then anchoring them by cable to ground level. This technique increases ductility and obtaining a more resistant structure adding a material that can resist tension.

This technique goes well with curve and arch shape structures. We can use application of high-performance materials (i.e. FRP, steel, wood, plastic) on the external sides of the wall, locally (i.e. strips). The connection with the masonry parameter is normally obtained with the use of epoxy resins or mortar. An effective use of this technique requires certain regularity in the masonry surface. In arches and vaults reinforcement can be applied between the extrados and an additional masonry layer.

Figure 4.31, external reinforcement

4.2.1.6. Anchoring by Cable

In the north part of castle we have inclination of the masonry wall toward outside, and it was discussed before we recommended using external reinforcement in order to increase the ductility and obtaining a more resistant structure adding a material that can resist tension. After this step, it is better to anchor the wall to ground by using cable to improve the stability of the structure, limiting eventual deformations.

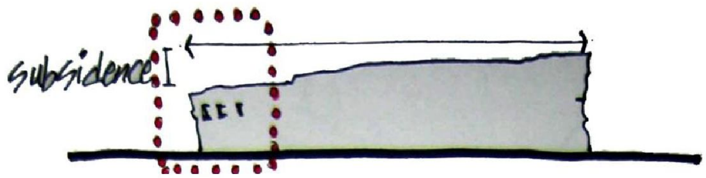
The steel cable intervention has soft visual impact and effective results, stainless steel's versatility, strength and durability permit the consolidated structure to be easily maintained and kept under control over time by progressively tightening tie bars13.

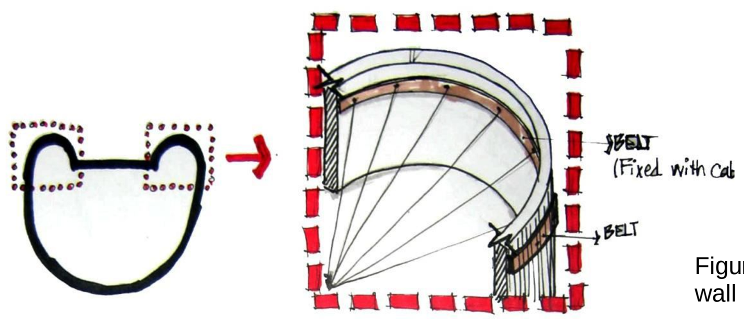
Steel cable stirrups can be used to support and constrain the damaged wall. By the connection to masonry wall, the better application in using steel cable is the post stressed cable elements method. Afterwards, a post-tension can be added to the cables to post-compress to the brackets

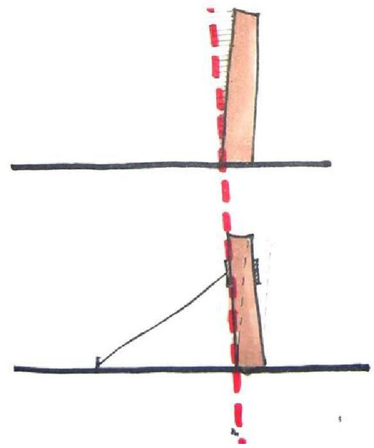
Figure 4.32, anchoring walls by cable

4.2.1.7. Subsidence at the northern part and metal belt

Using a belt around the rounded casements of the northern part of the castle both in outer and inner side of the walls is proposed. As it is shown in this sketch below, these belts are fixed to the ground by some cables from the inner side of the wall. This way we can deal with inclination of the walls.







Figures 4.33, 4.34, 4.35, subsidence of the wall and metal belt solution

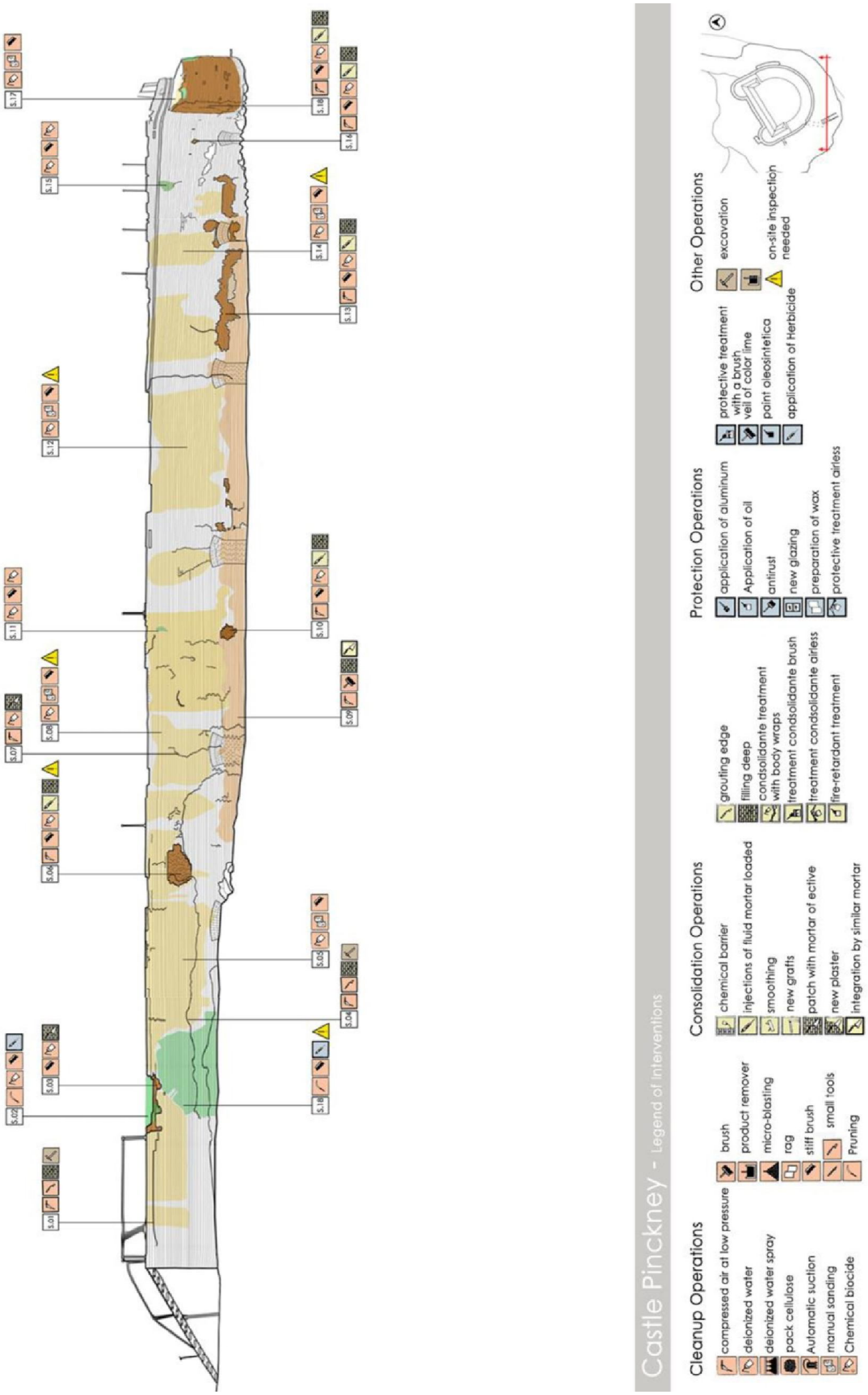
4.2.1.8. Uretek Slab-Lifting

In the parts that we are facing ground subsiding, it is recommended to use Uretek Slab-Lifting and Deep-Injection Raising and re-leveling, carried out by injecting expanding geo-polymeric structural resins under the element to be raised, through tiny 6 or 16mm holes. Experienced technicians inject the appropriate Ure-tek resins through tiny pattern drilled holes, immediately below the slab or footing. The components are precisely machine mixed and chemically expand almost immediately, exerting a mould pressure that fills voids encountered, re-establishing or confirming structural support. They cure, almost immediately, to a strong stable and long lasting material that is immediately trafficable and environmentally neutral. Uretek Slab-Lifting and Deep Improving ground bearing capacity is achieved by this patented technology that compact foundation soils, again by similar injection through tiny holes but down to multiple depths in weak strata.

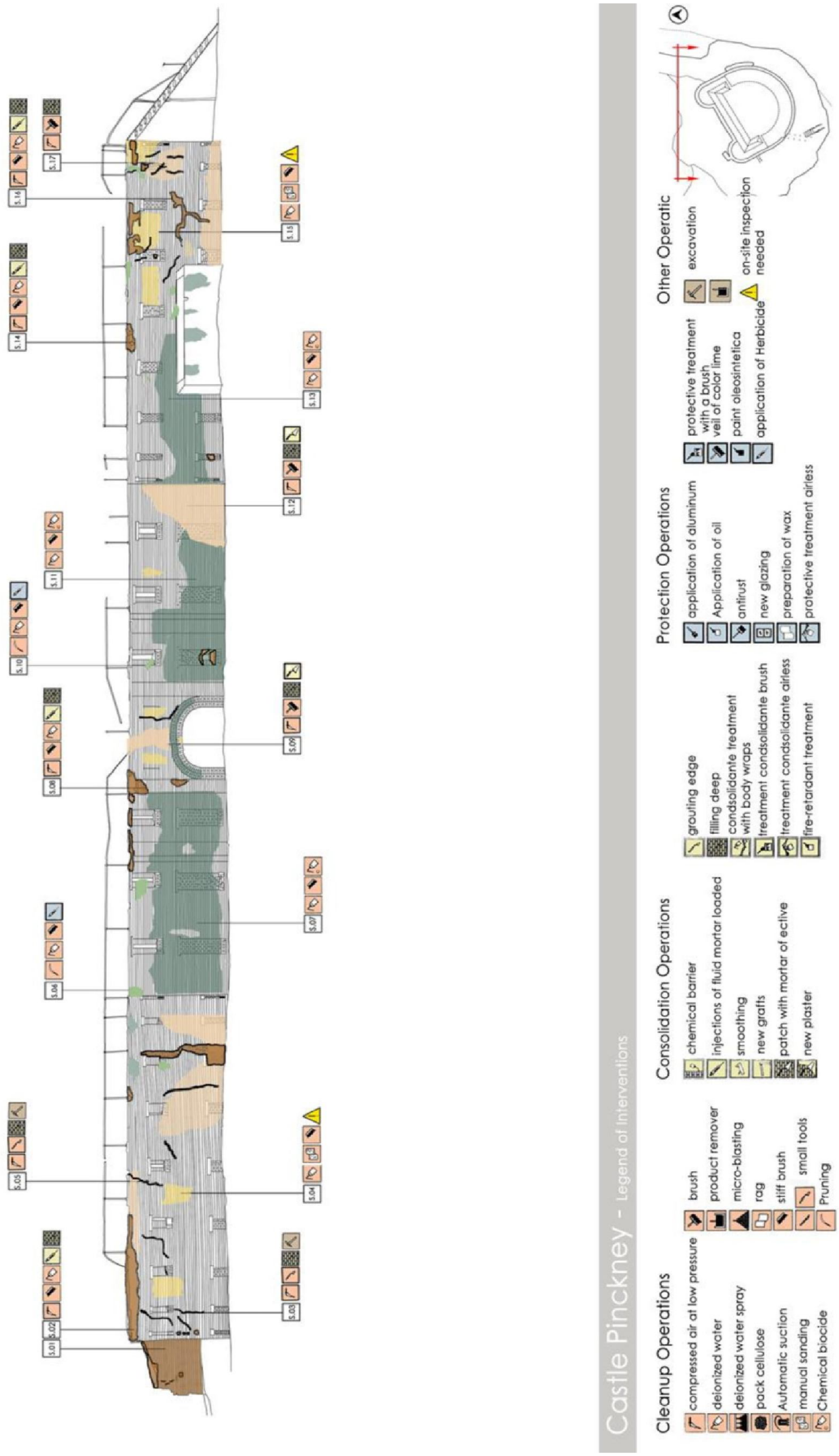
Figure 4.36, slab lifting solution

4.2.1.9. Uretek Power Piles

It patented and initially being offered as UPP Compaction, prefabricated elements are inserted through 34 or 38 mm Ø holes and expand up to 340 mm, allowing a concentration of soil densification in a very defined volume. Structural versions of UPP's are to provide pile-type support with skin friction and end bearing characteristics



Castle Pinckney - Legend of Interventions
Cleanup Operations
compressed air at low pressure
deionized water
deionized water spray
pack cellulose
Automatic suction
manual sanding
Chemical biocide
brush
product remover
micro-blasting
rag
stiff brush
small tools
Pruning
Consolidation Operations
chemical barrier
injections of fluid mortar loaded
smoothing
new grafts
patch with mortar of ective
new plaster
integration by similar mortar
grouting edge
filling deep
condsolidante treatment with body wraps
treatment condsolidante brush
treatment condsolidante airless
fire-retardant treatment
Protection Operations
application of aluminum
Application of oil
antirust
new glazing
preparation of wax
protective treatment airless
protective treatment with a brush
veil of color lime
paint oleosintetica
application of Herbicide
Other Operations
excavation
on-site inspection needed


Castle Pinckney - Legend of Interventions
Cleanup Operations
compressed air at low pressure
deionized water
deionized water spray
pack cellulose
Automatic suction
manual sanding
Chemical biocide
brush
product remover
micro-blasting
rag
stiff brush
small tools
Pruning
Consolidation Operations
chemical barrier
injections of fluid mortar loaded
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new grafts
patch with mortar of ective
new plaster
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fire-retardant treatment
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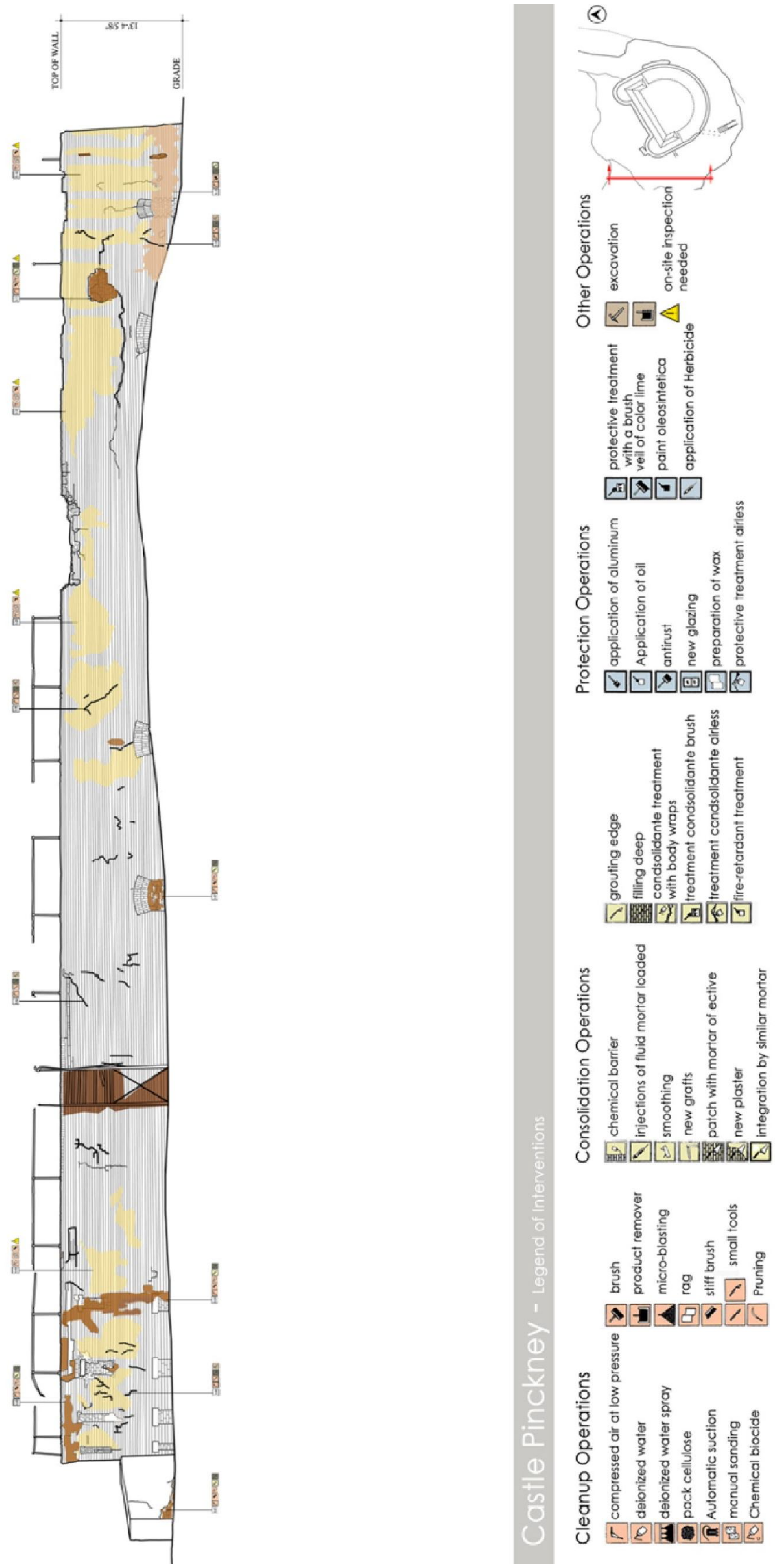
TOP OF WALL
GRADE
13'-4 5/8"
Castle Pinckney - Legend of Interventions
Cleanup Operations
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manual sanding
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product remover
micro-blasting
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small tools
Pruning
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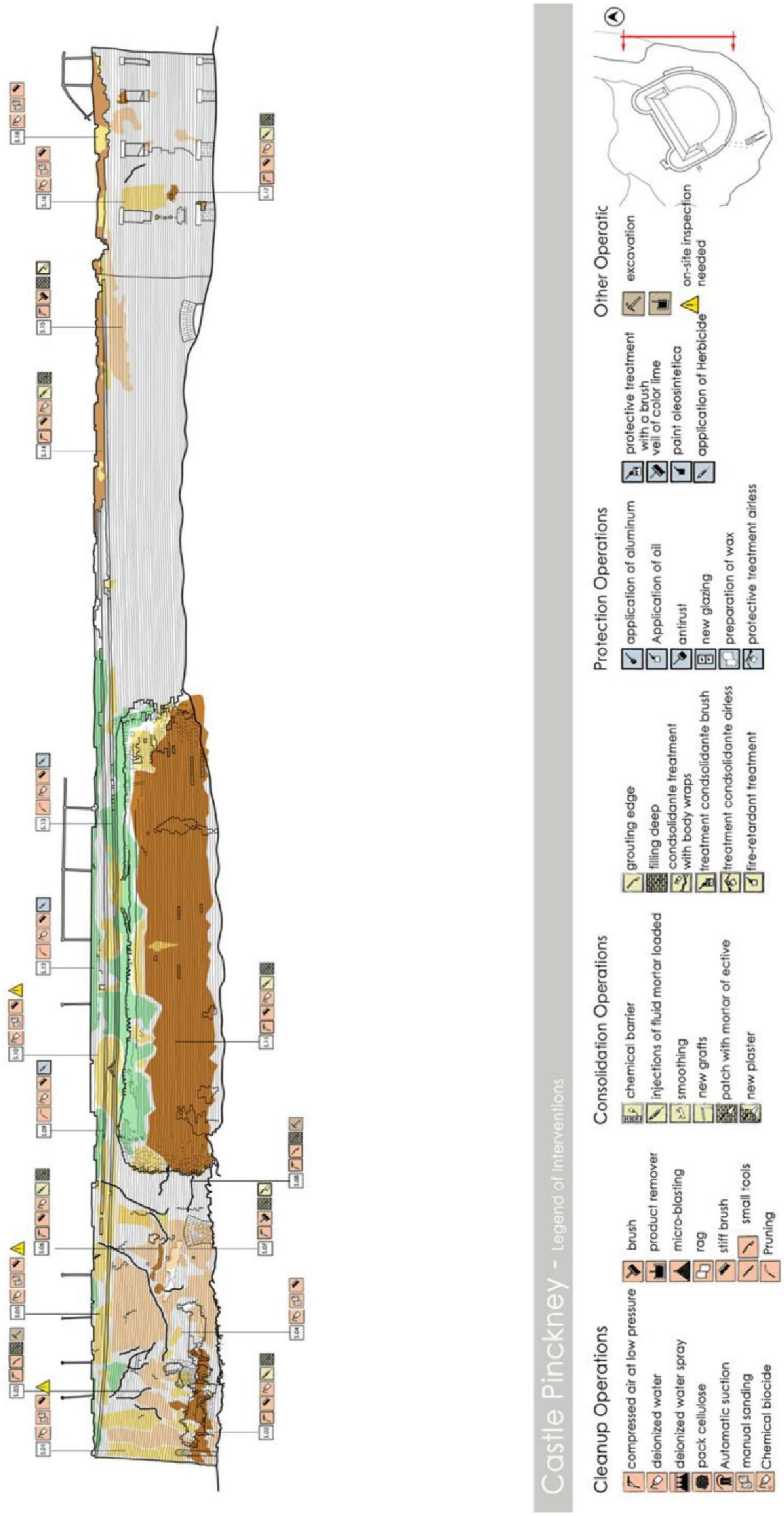
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rag
stiff brush
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Consolidation Operations
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injections of fluid mortar loaded
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grouting edge
filling deep
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treatment condsolidante brush
treatment condsolidante airless
fire-retardant treatment
Protection Operations
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new glazing
preparation of wax
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protective treatment with a brush
veil of color lime
paint oleosintetica
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on-site inspection needed

Chapter 5

Architectural Design

Chapter 5

Architectural Design (The Pier)

5. Pier Design

Our vision about RETHINKING CASTLE PINCKNEY FOR THE 21ST CENTURY gave us the inspiration of extending our area of interest to the whole Charleston waterfront which is facing the Shutes Folly Island and Castle Pinckney as a part of the urban scale context, defining three main nodes at the Waterfront (as explained in Chapter 2), connecting them together with a main (middle) node which has the best location regarding Castle Pinckney in accessibility and visual connection (waterfront pier), where we will connect the waterfront side with Island and the Castle.

Our main goals are listed below:

- Refurbishment of the Pier. Giving new functions (Castle Pinckney's boat dock, relaxation zones, belvedere and restaurant)
- Building the structure which is comfortable for visitors all over the year. Providing shelters to protect them from rain and the sun, and in the northern part to protect from wind.
- Providing good visual connection to the Castle through the orientation of the boat's dock and also the parts introduced as belvedere in our project.

These goals are achieved by refurbishing existing pier, extending the canopies with a wooden structure which is a local material, putting the welcome desk comprised of ticket and information office for Castle Pinckney visitors at the lower level with the new direct ferry stop to the Island, adding a belvedere with a panoramic view to the sea shore and the Island and by adding a new level as a restaurant served by a traditional food of Charleston.

The building employs concrete platform’s supporting structure, covered with wooden desk, protected from environmental impact. Proposed wooden square-shaped serial planes give a feeling of self-supporting structure, which rises from the water and, in some parts, lies on the top of the round columns, which are the parts kept intact after demolishing of the existing shelters’ roofs.

The main body of the pier complex is a cantilever construction oriented on the visual axis to the Island. This linear organization allows having a spectacular view to the harbor and to the sea and at the same time to draw tourist’s attention.

5.1. Pier and Sustainability

Through this project we will do the technology and sustainability considering “Charleston green plan“. Our design goal must satisfy local constrains and requirements of city Charleston.

PV solar glass is installed on the plane shelter’s roof and on the top of the restaurant. Solar energy provides electricity and artificial light during the night.

In the restaurant, natural light is provided through a linear slot of windows at a height of 4 meters along the Southern, Eastern and Western facades, while vertical and horizontal shading systems are installed on the south and east part of a glazed façade respectively. The terrace roof also helps providing shading.

5.2. Inspiration

The very first inspiration of the project was The High Line Park in New York, United States. It is a one-mile New York City linear park built on a 1.45-mile section of the elevated former New York Central Railroad spur called the West Side Line, which runs along the lower west side of Manhattan; it has been redesigned and planted as an aerial greenway. The linear shape of this refurbished railroad was the preliminary idea of our pier design.

Figure 5.1, High Line Park, New York

Figure 5.2, High Line Park seating area

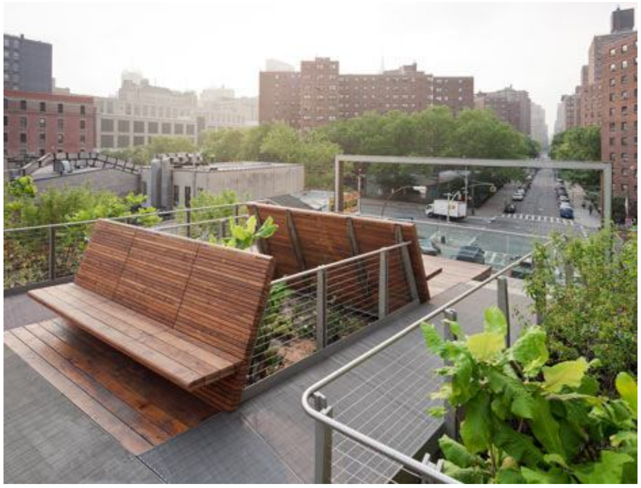


Figure 5.3, High Line Park's benches

5.3. Conceptual Approach

The architectural project aimed to refurbish the old Pier respecting traces of the previous design (concrete columns), giving a new function and to continue the urban fabric by orientating the tourist flow into the Shutes Folley Island.

Two levels of the structure share same activities, such as communication, learning from the past, enjoying the view and local cuisine.

As mentioned before, we respected traces of the past in our design. Underwater supporting columns remained intact (except for the metal roofs which are demolished). On the pier level, old shelter's supporting elements are supposed to be without significant changes and with the same rounded shape.

In the plan new seating areas are added:

- Stairs – to have a rest next to the water while enjoying the views
- Wooden tables and benches – relaxation zone
- At the same level welcome desk (ticket and information office) for the Castle Pinckney visitors
- The new direct ferry stop to the Island. Considering the depth of the water around the main pier, this ferry stop deck is located at the end of the main pier perpendicular to it.

Significant changes are done in regards to the upper level where the belvedere with a panoramic view to the sea and the Island is added. It can be reached by the system of elevators and ramp.

5.4. Design diagrams

- Figure 5.4 illustrates the current situation of the existing pier with three existing shelters which are proposed to be demolished in this refurbishment project.
- Figure 5.5 illustrates the pier after removing the demolished shelters' roofs. As it can be seen, all the existing columns are kept intact in order to be used in the refurbishing plan of the pier as a support for the new structure we added.
- Figure 5.6 illustrates the parts added to the existing pier on the lower level after demolishing a small part at the southern part. These added parts are comprised of seating areas at north, resting areas (stairs on both sides of the pier) at south and a small dock as a ferry stop towards the Island and Castle Pinckney.
- Figure 5.7 illustrates serial planes added on the top of the existing columns. These successive planes are used to emphasis the linear shape of the pier and to make the visitors walking to the main parts of the project which are ticket office, ramp and ferry stop.
- Figure 5.8 illustrates covering defined on the seating areas to protect the visitors from the sun when they are seating and enjoying the views. In addition, PV panels are proposed to install on the top of these roofs in order to provide the electricity for the pier.
- Figure 5.9 shows adding a restaurant serving traditional foods and drinks of Charleston at the new level.

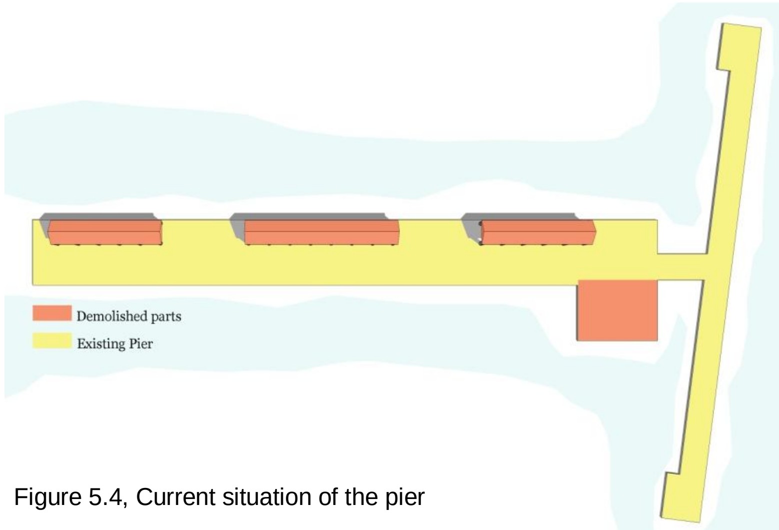


Figure 5.4, Current situation of the pier

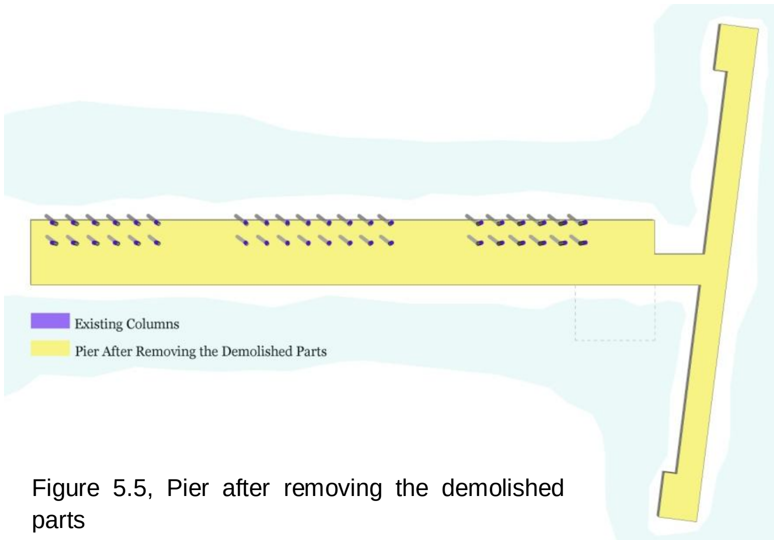


Figure 5.5, Pier after removing the demolished parts

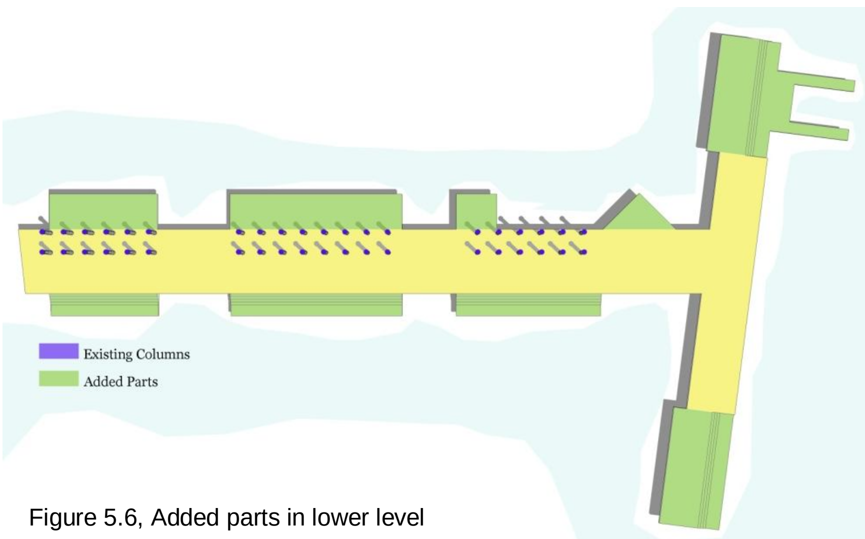


Figure 5.6, Added parts in lower level

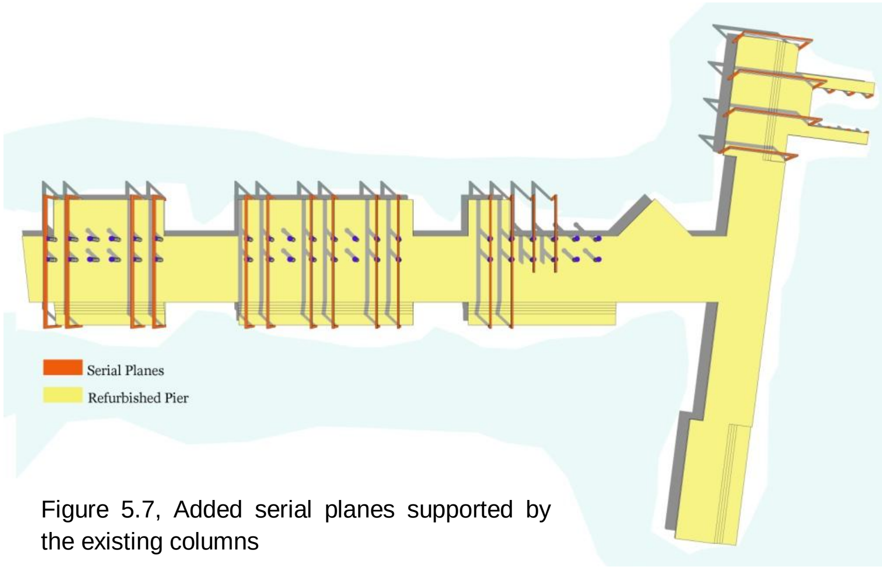


Figure 5.7, Added serial planes supported by the existing columns

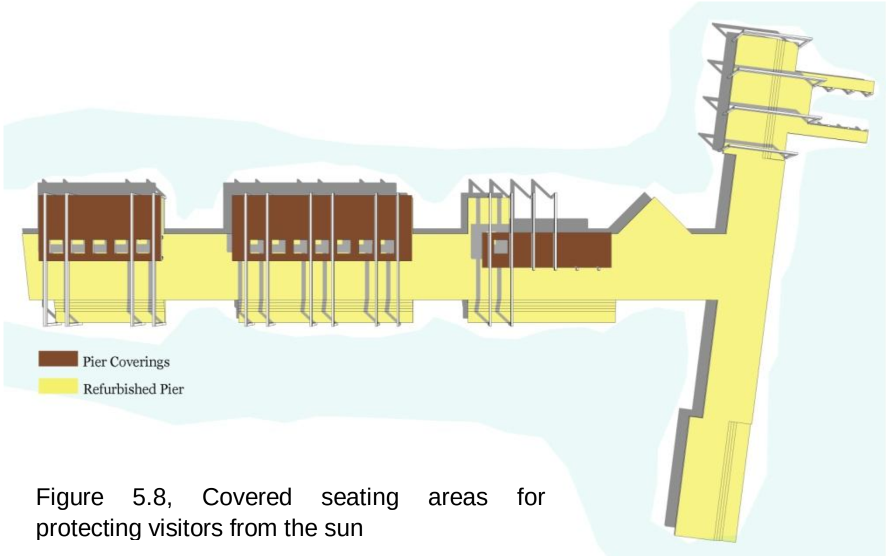


Figure 5.8, Covered seating areas for protecting visitors from the sun

Figure 5.9, Added restaurant in upper level

5.5. Functions

- Seating area:

Added parts on the northern side of the pier are defined as seating areas. These are furnished by wooden benches (local material) and give the visitors the opportunity of taking advantage of the surrounding views to the sea shore and to the city.

- Resting area (stairs):

Added parts on the southern side of the pier include stairs in order to provide a separate area along the walking path for the people who desire to take a quick rest while they can enjoy the views towards the Castle and the surroundings.

- Covered passage:

Existing columns and the new covering added on their top provides a covered passage guiding people towards the ticket office, restaurant and ferry stop. The transparent PV panels on the top of this passage provide a harmony of the sun and shadow inside this passage.

- Ticket & information office (welcome center):

Welcome center is located in the middle of the refurbished pier, where visitors can decide whether to go to the restaurant or to the ferry stop and visit the Castle.

- Ferry stop:

Ferry stop is added on the northern part of the pier perpendicular to the main one. It is served by the boats which transfer visitors to the Island.

- Ramp:

It is used as a main access towards restaurant. Additionally, considering its location, it is considered as a part of the belvedere.

- Restaurant:

It serves typical foods and drinks of Charleston while with a rotation towards the Castle can provide a panoramic view for the people eating there.

- Terrace of the restaurant:

As it is mentioned, the restaurant terrace is also considered work as a part of the belvedere.

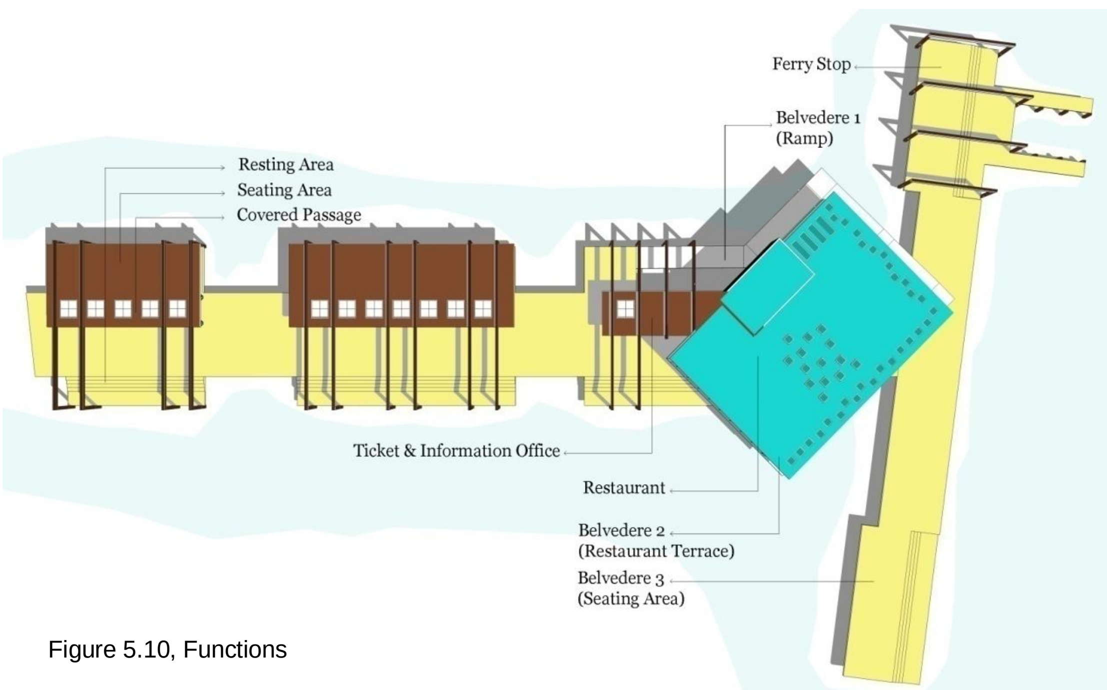


Figure 5.10, Functions

5.6. Circulation and Accesses

5.6.1. Horizontal Circulation

As illustrated in figure 4.11, one can start walking along the pier choosing different circulation shown in different colors. The first is the red line defining the circulation towards the ticket office and ferry stop respectively. The second possible circulation would be the one shown in blue which starts from the covered passage and at the end can split into two, one goes to the restaurant and one goes towards the ferry stop.
Yellow lines define the path to the seating and resting areas.

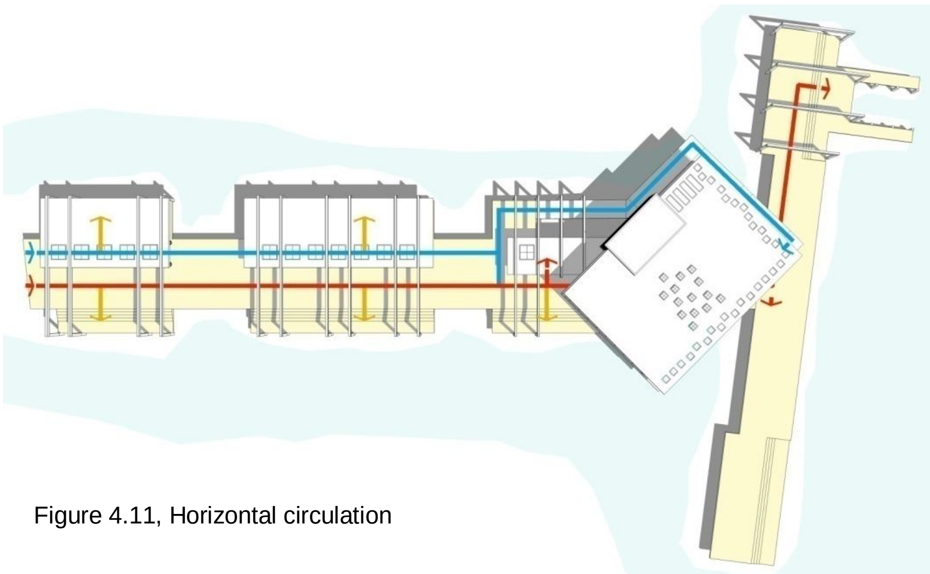


Figure 4.11, Horizontal circulation

5.6.2. Vertical Access

Vertical access to the upper level of the project (Restaurant) is mainly through a ramp located on the north end of the pier. Additionally, a transparent elevator located next to the ticket office eases the access to the upper level while it can also be used by the restaurant's staffs to transfer foods and other stuffs. The transparency of the elevator is considered in order to not block the visual access to the surroundings. Moreover, it lets the visitors to see the views while they are going up to the restaurant.

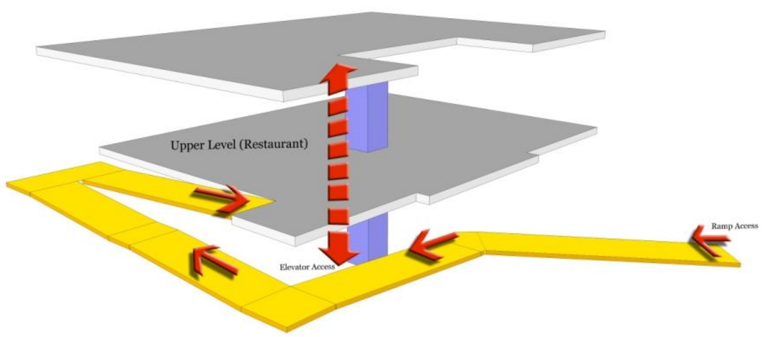


Figure 5.12, Vertical access

5.6.3. Ferries' Circulation towards the Island

Ferries to the Castle do not follow the path 1 shown in figure 4.13, as the idea of our project is to use the path 2 in order to get to the Castle. According to our idea, by using circulation line 2 for getting to the Island, we give the opportunity of visiting the southern side of the Castle to visitors while the boat is approaching the Island. As it was explained in previous chapters, the Island has a marshy land and we decided to minimize the interventions on it as much as possible. Thus, by defining a new pier at the other side of the Island, in a direction where is not be seen directly from the city, we achieved this goal.

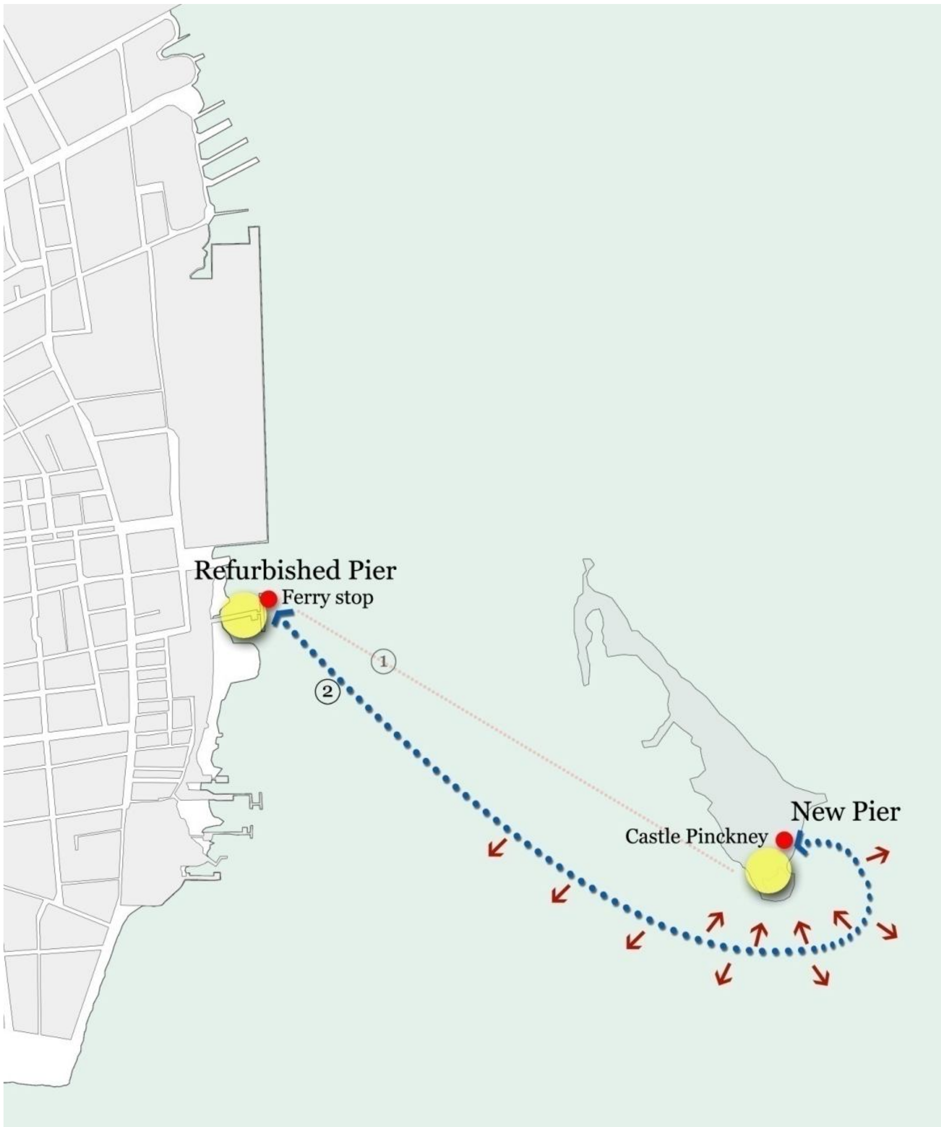


Figure 5.13, Ferries' circulation to the Castle

5.7. Form blow up

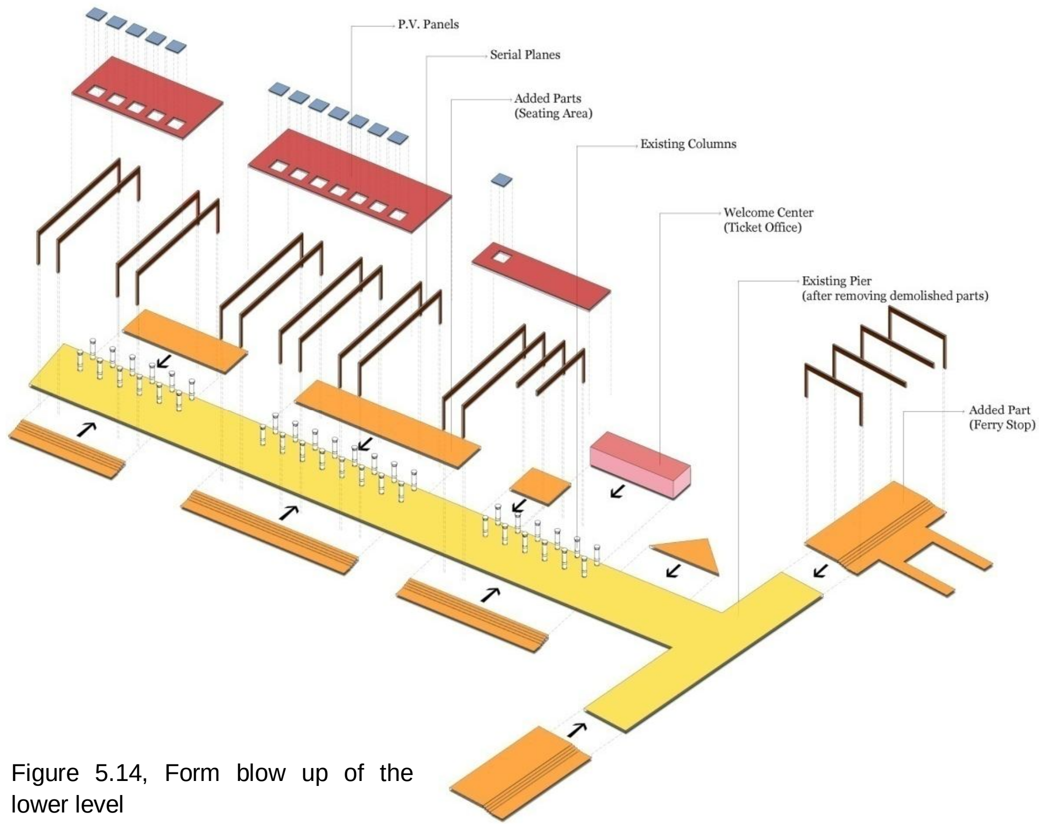


Figure 5.14, Form blow up of the lower level

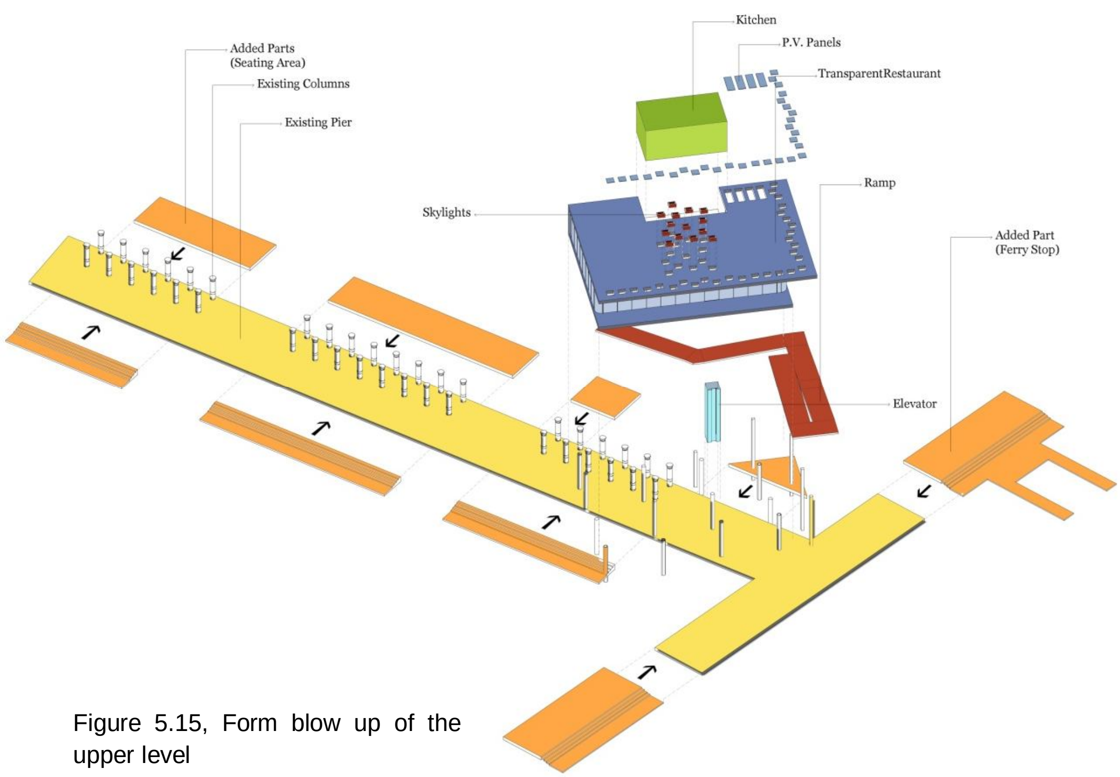


Figure 5.15, Form blow up of the upper level

5.8. Design proposal
5.8.1. Layout

The aim of this project was giving the life back to the old Castle Pinckney by connecting the Island to the city using the pier which had the best location in terms of visual access and vicinity to it. All the parts previously explained are designed in order to achieve this goal, from the seating areas added to the existing pier, added welcome centre, and ferry stop till the restaurant on the second level with the orientation towards the Castle.

5.8.2. Plans

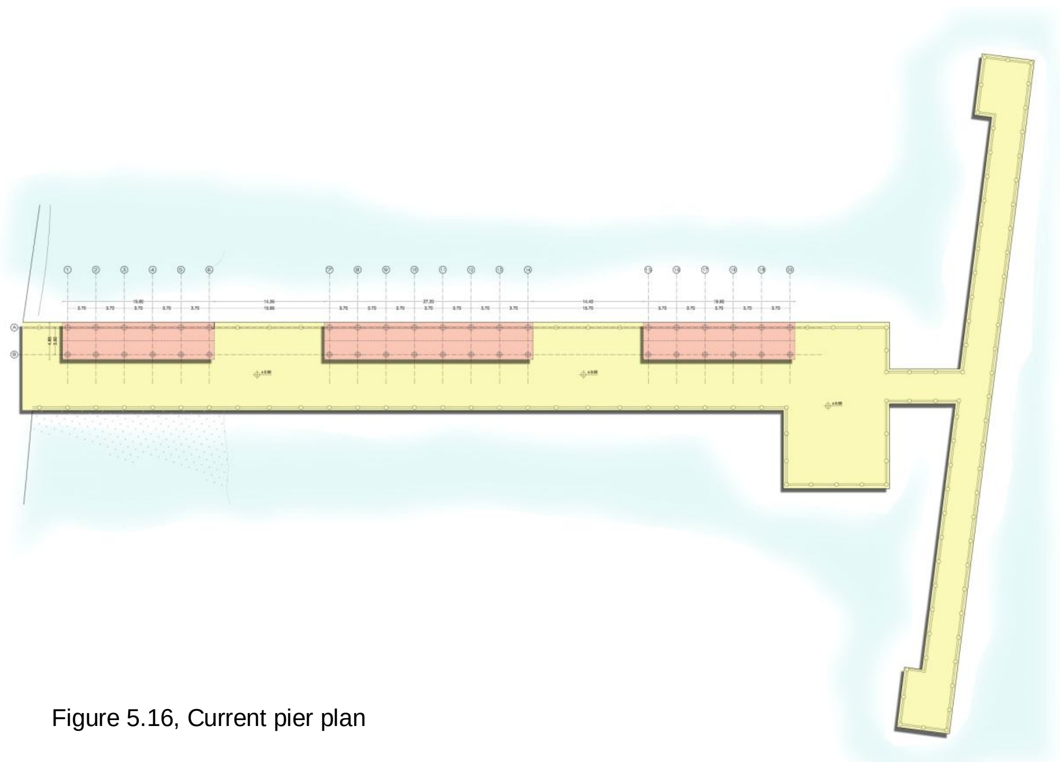


Figure 5.16, Current pier plan

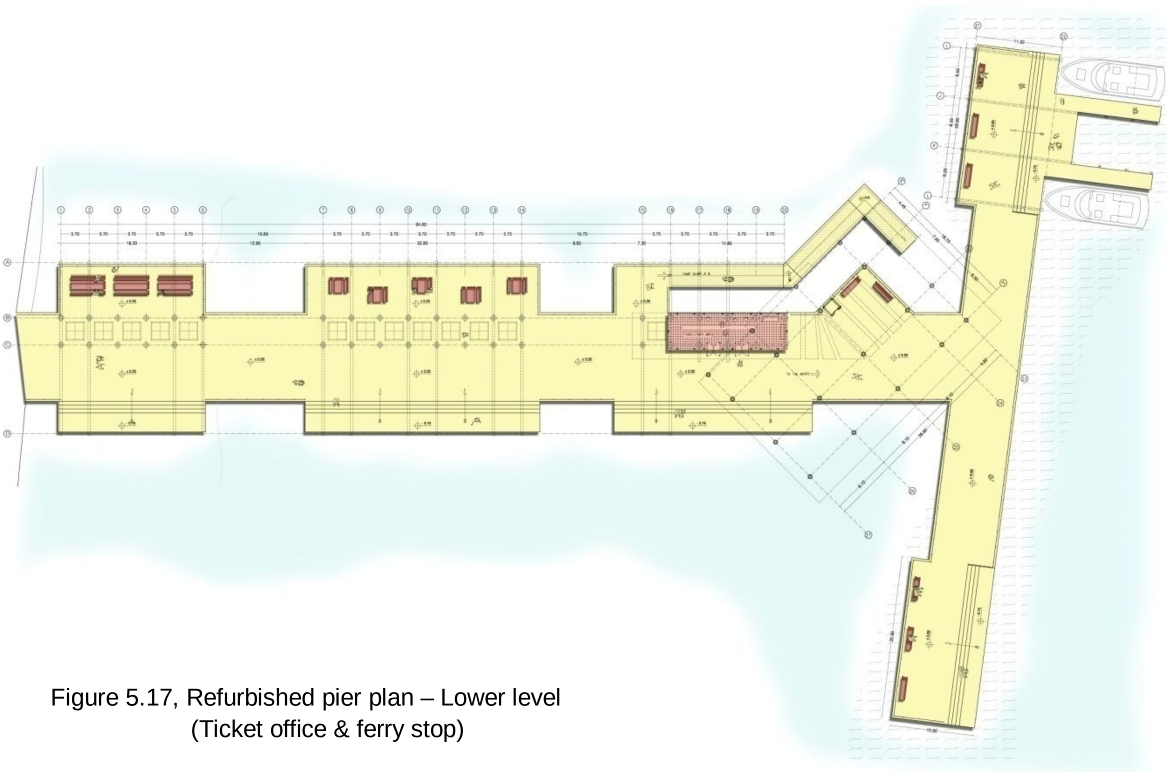


Figure 5.17, Refurbished pier plan – Lower level
(Ticket office & ferry stop)

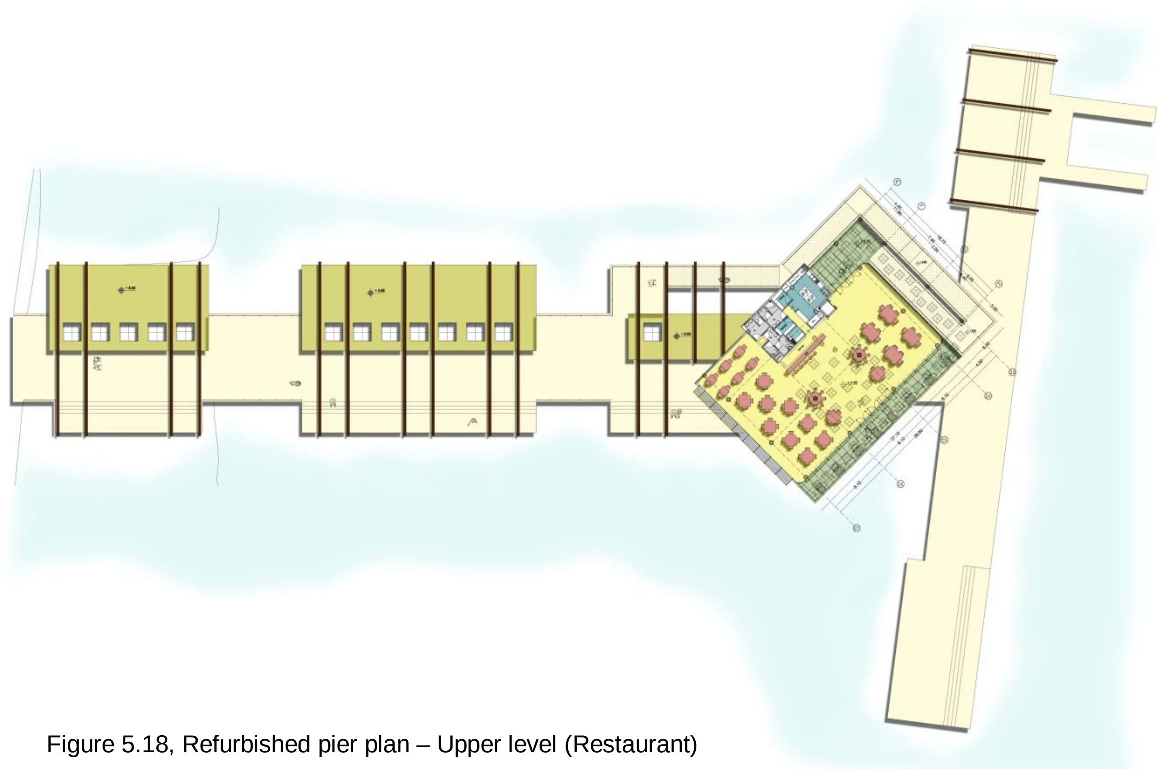


Figure 5.18, Refurbished pier plan – Upper level (Restaurant)

5.8.3. Pier and Restaurant Elevations

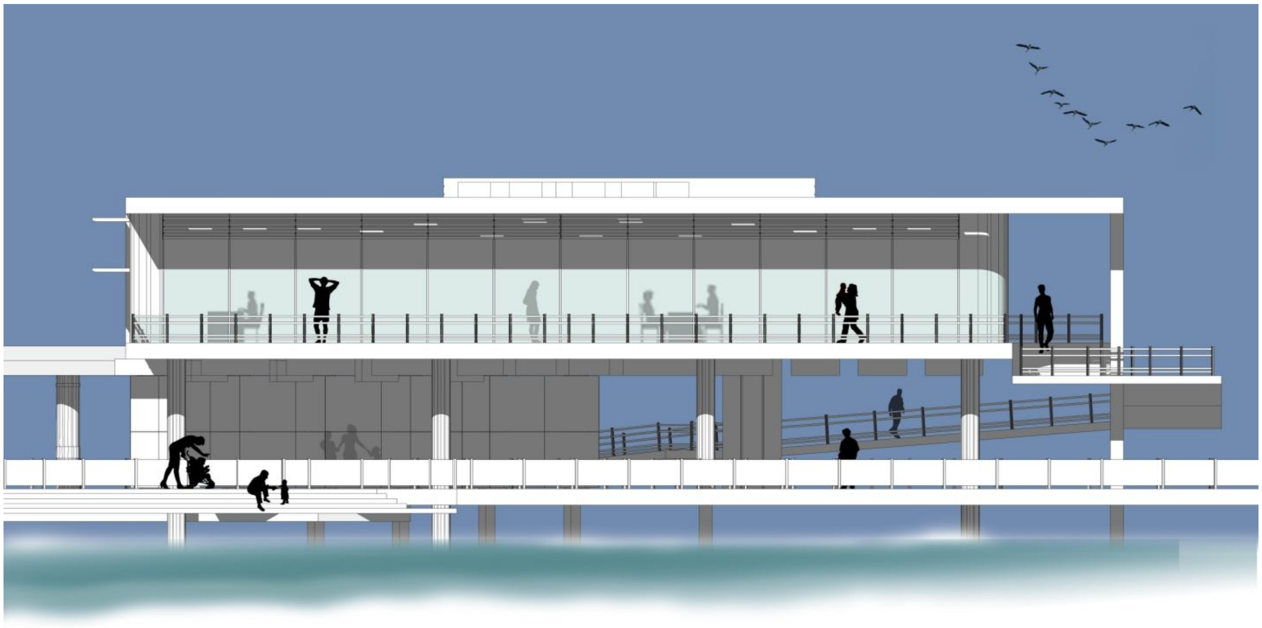


Figure 5.19, South elevation of the restaurant

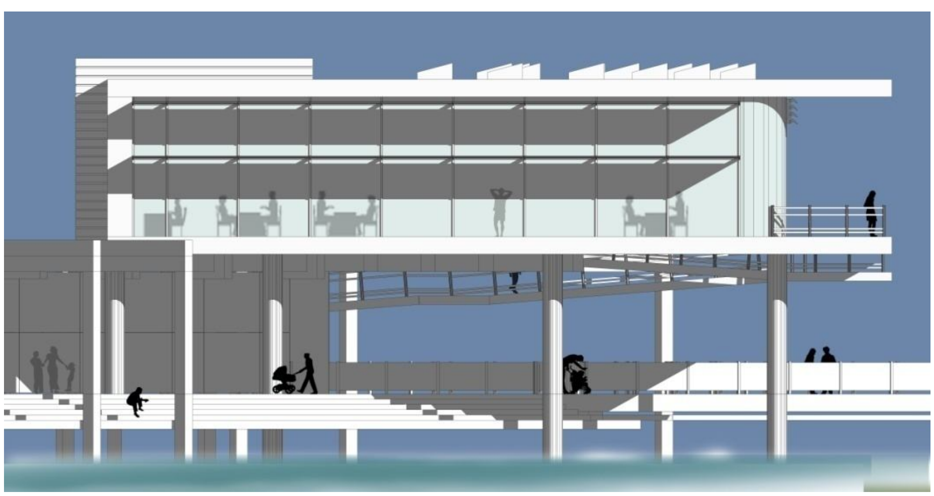
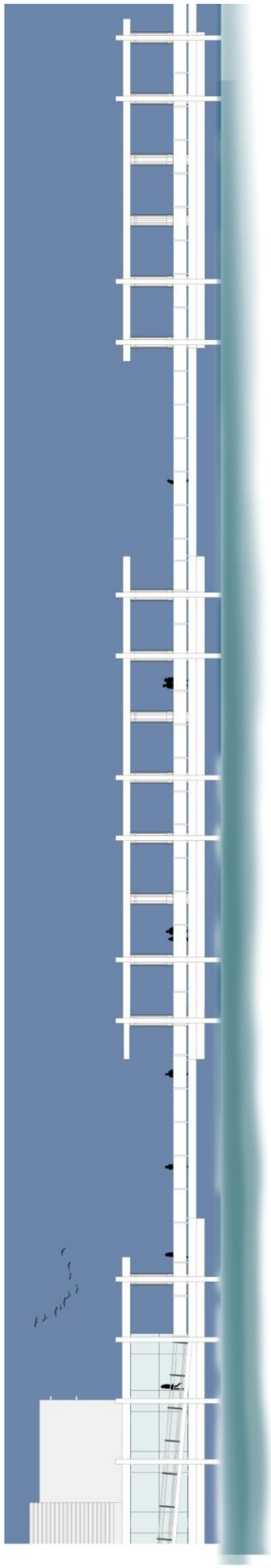
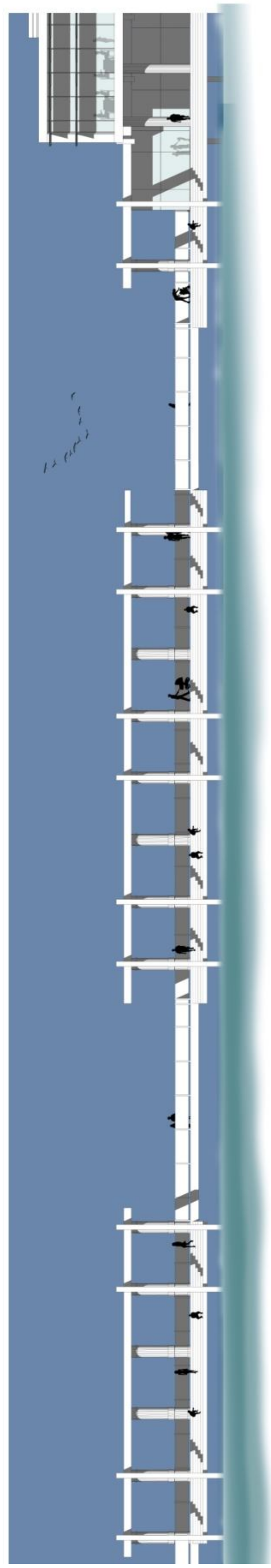


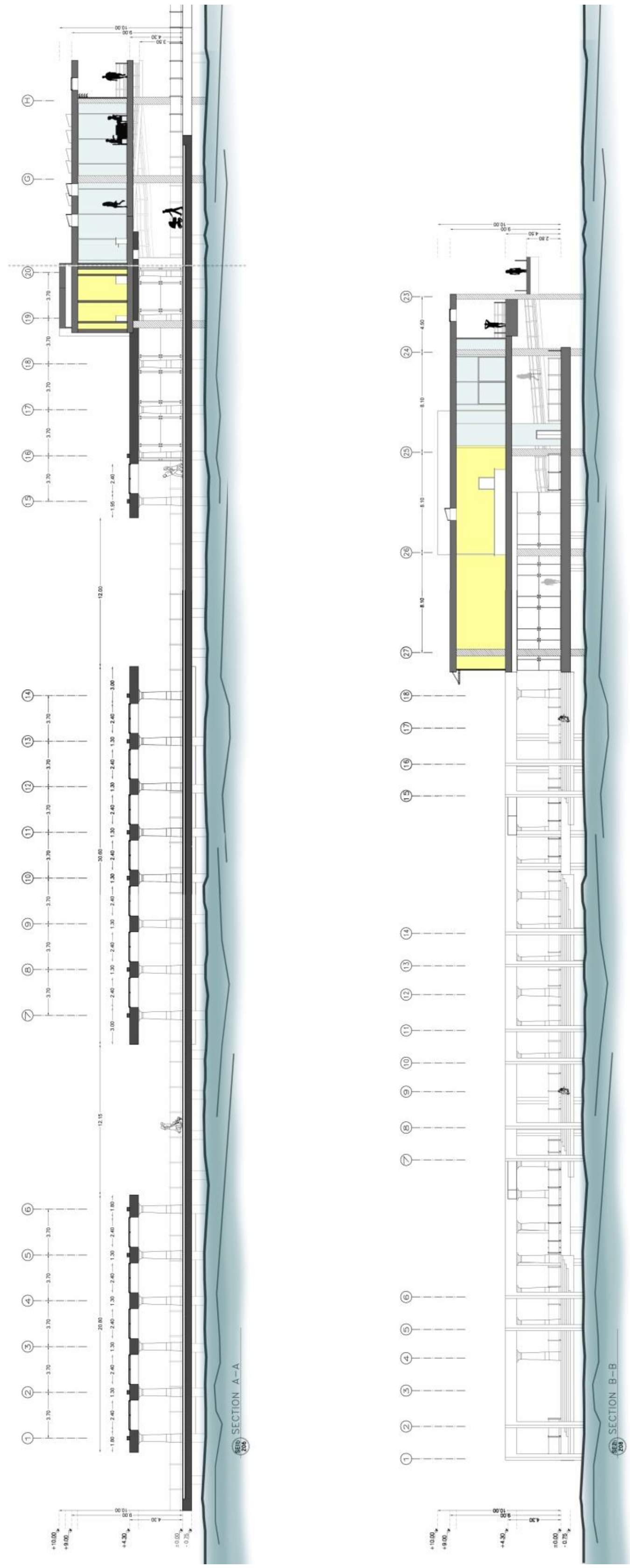
Figure 5.20, East elevation of the restaurant





Figures 5.21 and 5.22, north and south elevation of the main pier

5.8.4. Sections



Figures 5.23, 5.24, Pier and restaurant sections

5.9. Perspective Analysis
5.9.1. Restaurant Design

In this project, as previously mentioned, it was also proposed to build a small restaurant to serve the typical foods and drinks of Charleston. The idea was to equip this restaurant with all is needed to serve a simple foods and beverages, while the idea was mostly to bring visitors and locals together to enjoy the panoramic view of the surrounding and also the Castle while they are serving with typical foods. This would make their stay more memorable in their minds.

In addition, the idea was to make this restaurant transparent as it has been oriented to get the best orientation towards the Castel in order to take advantage of the panoramic views. In this case it can be also used as a part of our Belvedere.

5.9.1.1. Louvers

Both wooden and metal Louvers can be found in Charleston. The metal ones were chosen in this project in order to give more compatibility and harmony to the material of the whole volume of the restaurant.

Both vertical and horizontal were applied to the restaurant. Vertical louvers to the east glazed façade and two rows of the horizontal ones were added to the south glazed façade. More information and analysis about how to provide shadings in the restaurant can be seen in technological design chapter.

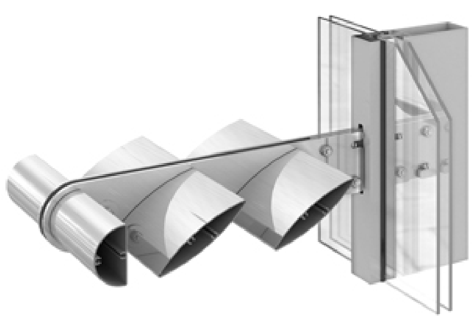


Figure 5.25 Horizontal louver of the restaurant

Figure 5.26 Vertical louver of the restaurant

5.9.2. Pier Exterior Views

Figure 5.27, Pier seating areas

Figure 5.28, View of the ticket & information office

Figure 5.29, View of the ferry stop and restaurant access by ramp

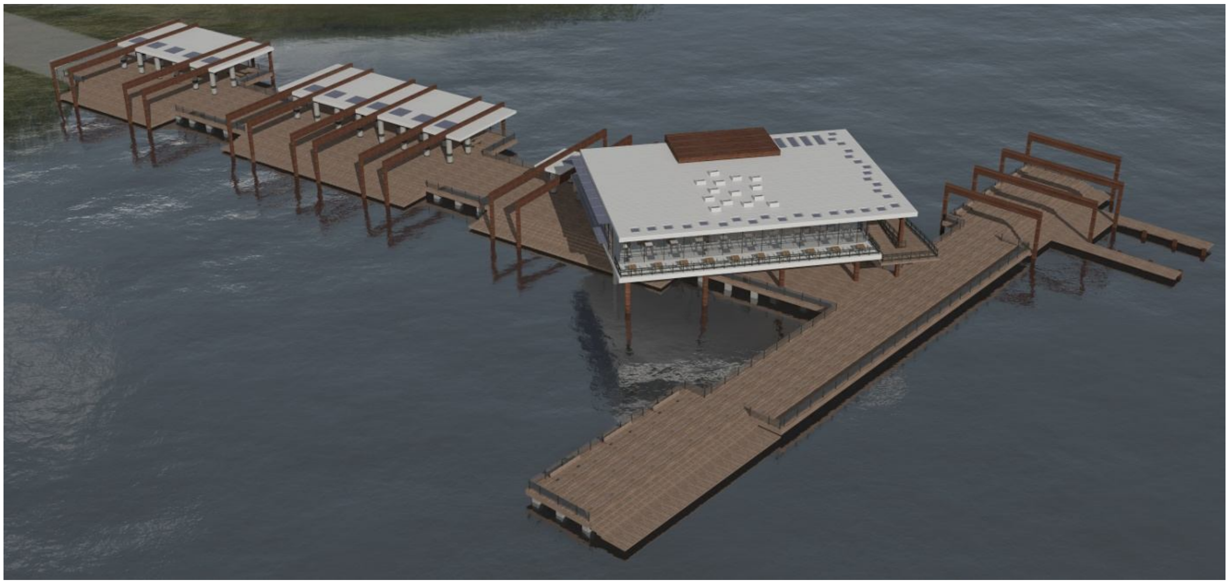


Figure 5.30, View of the refurbished pier

Figure 5.31, Interior view of the restaurant

Figure 5.32, View of the refurbished pier

Figures 5.33 and 5.34, Refurbished pier view from the waterfront park

5.10. Materials

In order to choose the materials which are more compatible with the materials of the context we were working, we tried to choose typical materials of Charleston. Materials identified as the most used in the buildings scattered around the city were mostly wood (even wooden louvers in addition to the metal ones) and white siding.

Based on the recognition about Charleston building materials, our material were chosen for this refurbishment project as:

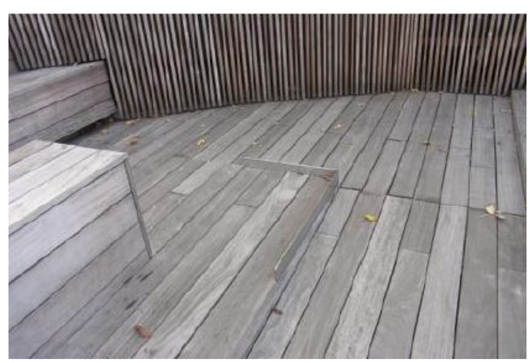
- White siding:

White siding is chosen for the restaurant, as the every first concept of adding a new level was to have a floating volume at the end of the pier to attract visitors.

Figure 4.35 White siding in Charleston

- Wood:

Material chosen for serial planes is wood as they are in contact with water, so the idea of using metal columns refused. Moreover, wood is the typical material abundantly found in Charleston so it would be a good solution due to its availability and compatibility with our design.



Figures 4.36, 4.37 wooden pavement in Charleston

Another part that wood were applied to is pavement of the new added parts to the main pier. As the main pavement is in wood (installed on a concrete-base structure), we also tried to choose sustainable decking solutions, by combining nature and technology.

Wooden pavement is used for the extension parts of the pier. In order to be recognizable even by the visitors, the new parts added to the pier on the lower level, we tried to use the same material for the paving (wood) but with difference in orientation of the wood planks for example, to make the new wooden pattern perpendicular to the existing one.

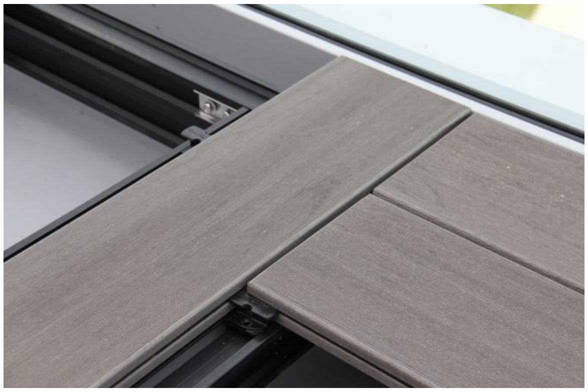
Figures 4.38, 4.39, 4.40 wooden pavement chosen for the project

This material, with the natural look of wood & the low maintenance of PVC, is durable and it is a good solution for us that were looking for an ecological pier design.
Talking about its safety, it should be mentioned that it is non slip flooring, as the decking floor fulfils the safety requirement perfectly. This anti slip flooring is perfectly suitable for our design as it can enhance the safety of the seaside environment of our design context.

Briefly speaking, the main advantages of this kind of decking we chose are:

- Low maintenance;
- Slip resistant, even when wet;
- Water resistant;
- Durable;
- Shatterproof
- Ecological (100% recyclable)

Decking system of the new wooden pavement is shown in these pictures:



Figures 4.41, 4.42, 4.43 decking system of the wooden pavement of the new parts

Architectural Design (The Castle)

Any effort to make Castle Pinckney accessible to the public, or to adaptively reuse the site, faces some obstacles. First and foremost is the fort's location, on an island in the harbor, requiring boat transportation to access the site. There is no utilizable dock on Shute's Folly Island. The island itself is low-lying and marshy, and covered with a dense low growth, which is not amenable to pedestrian activities. The fort itself, its interior completely filled with earth, presents little of obvious, outward historic interest. Which structures or foundations may survive under the fill is unknown. Extensive archeology would be required in the fort's interior to expose these remains.

5.11. Conceptual Approach

A reuse project of an old and monumental fort is not just a big and exciting challenge, but it also comes with great responsibility. The design should connect to the existing building but also provide something new and exciting.

The vision of this project was to emphasize the existing fort and give priority to that, instead of taking the attention from the old building to the new addition. We wanted to state that the new addition is just that; an addition to an existing building and not a new individual one.

We believe after the realization of vital & required interventions to Castle Pinckney, controlled public access to the fort & island with the concept of an art gallery inside it not only won't alter the brick structure and possible remaining parts but also make it alive again.

We think Castle Pinckney is not anymore a place to host cannons and soldiers instead it would be house of art, artists and visitors with an everlasting memory.

5.11.1. Roof design

Challenging the choice among different roof shapes. Study area analysis revealed tree different solutions regarding the protective envelope for Castle. Structural and Environmental comparison between proposed roof design

- **Structural approach**

Positive points:

+ Attractive for people approaching to the castle

Negative points:

- Not visible from Charleston

- Permanent structure

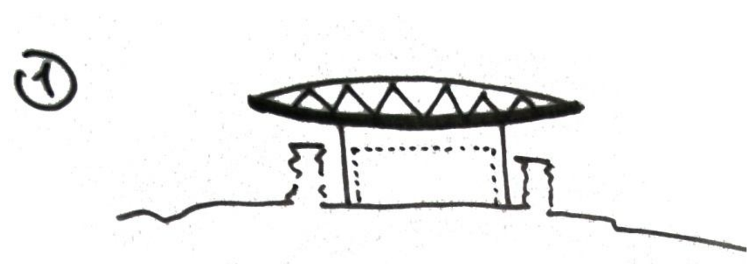


Figure 5.44, Roof design, variant 1

Positive points:

+ Appropriate for nature's preservation

Negative points:

- Not eye catching
- Not an aesthetic solution
- Permanent structure

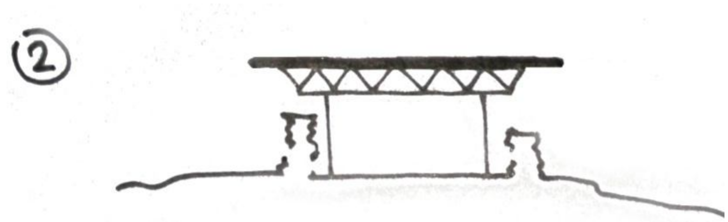


Figure 5.45, Roof design, variant 2

Positive points:

+ Reversible
+ Temporary structure
+ Noticeable from Charleston

Figure 5.46, Roof design, variant 3

- ➢ **Environmental approach**

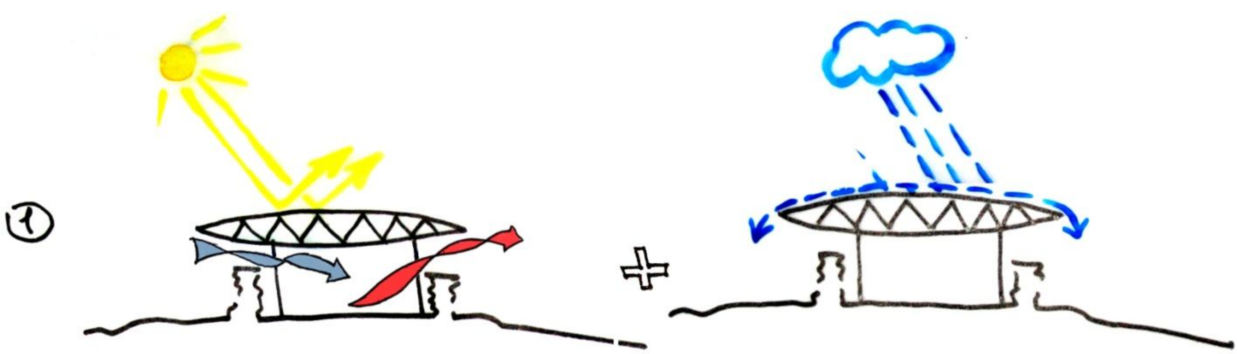


Figure 5.47, Environmental study, variant 1

Positive impact:

+ Guide water out of the castle
+ Attractive for people approaching to the castle
+ Good natural ventilation

Negative impact:

- Not visible from Charleston
- Luck of natural light inside the castle

Figure 5.48, Environmental study, variant 2

Positive impact:

+ Guide water out of the castle

+ Good natural ventilation

Negative impact:

- Not visible from Charleston

- Luck of natural light inside the castle

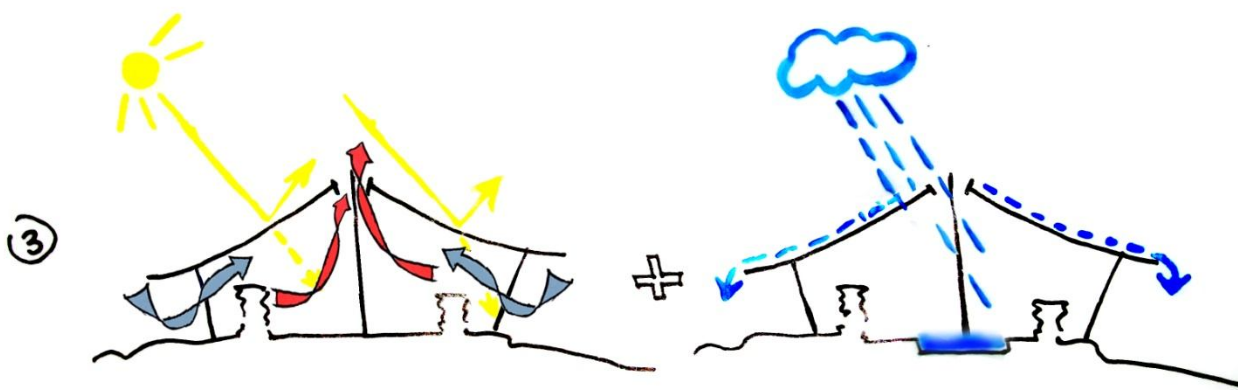


Figure 5.49, Environmental study, variant 3

Positive impact:

+ Good ventilation (Bernoulli effect)

+ Natural light inside castle (Semi-transparent tent)

Negative impact:

-Precipitations entering the castle

In order to discard negative impact of precipitations inside the Castle, we take an advantage of having water in the central pool. Using it as the natural habitat, which reflects the outside conditions around the Castle (wild nature)

- **Practical approach**

Challenging the design of tensile roof, we made several experiments with flexible material (ties) in order to understand how the real tensile structure will work.

Pictures of our experiment are shown below.

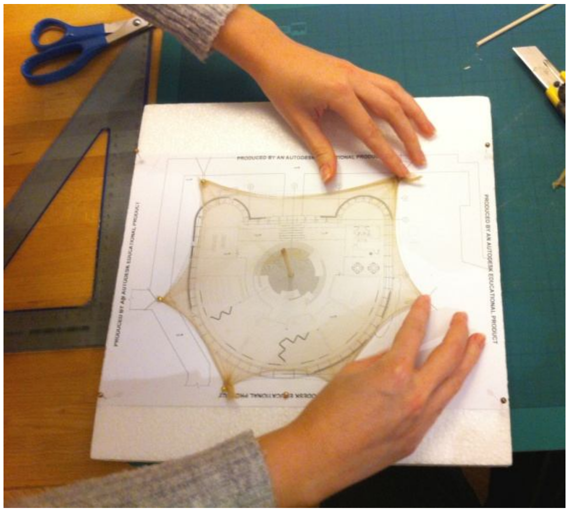


Figure 5.50, Studying process- Stretching flexible material

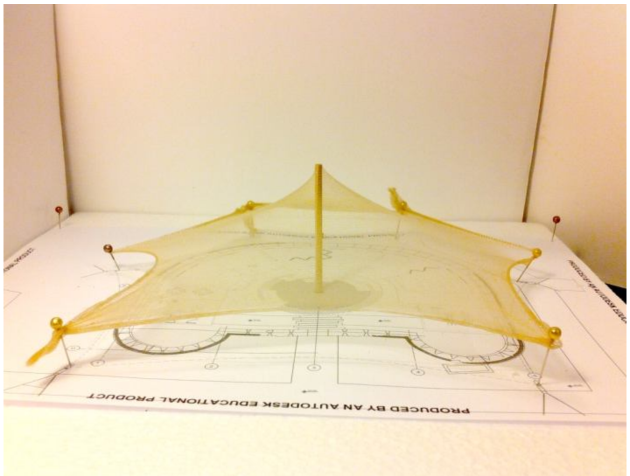


Figure 5.51, Physical model

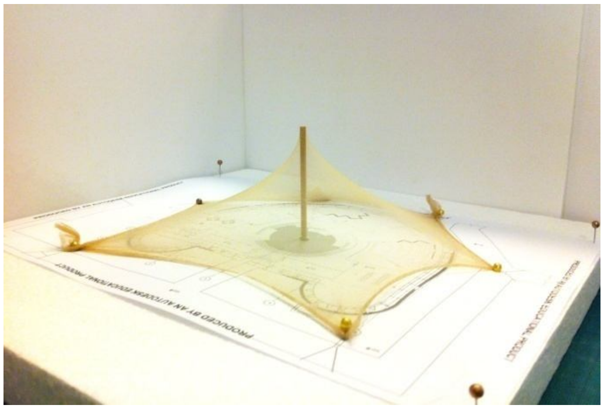


Figure 5.52, Physical model

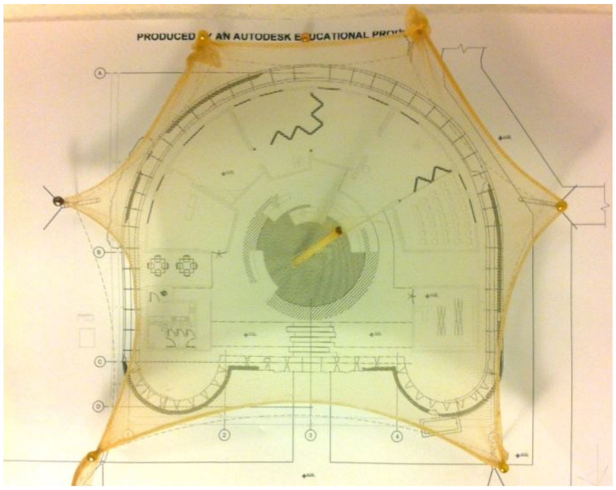


Figure 5.53, Physical model, top view

5.11.2. Gallery design

Our gallery design proposes a new, more efficient method of building through the use of building information modeling (BIM) and integrated component assemblies. The thousands of parts, which make up a building, are collapsed into a few dozen off-site fabricated assemblies that are simply attached to balloon frame system on site.

We use local material - wood, one of architecture's nobler materials, allows us to develop both complex structures and minimal designs.

The main design goal of our exhibition gallery was to create a closed, comfortable and intimate space that forms an immediate connection between visitors and exposition. The light wooden construction gives space and allows directing visitors through smoothly flowing one into another exhibition space.

The advantage of light structure is also that after some years the gallery boxes can be easily moved to the Charleston city employing new function, such as bar or shop. At the end of life they can be dismantled and the timber and boards re-used for other projects.

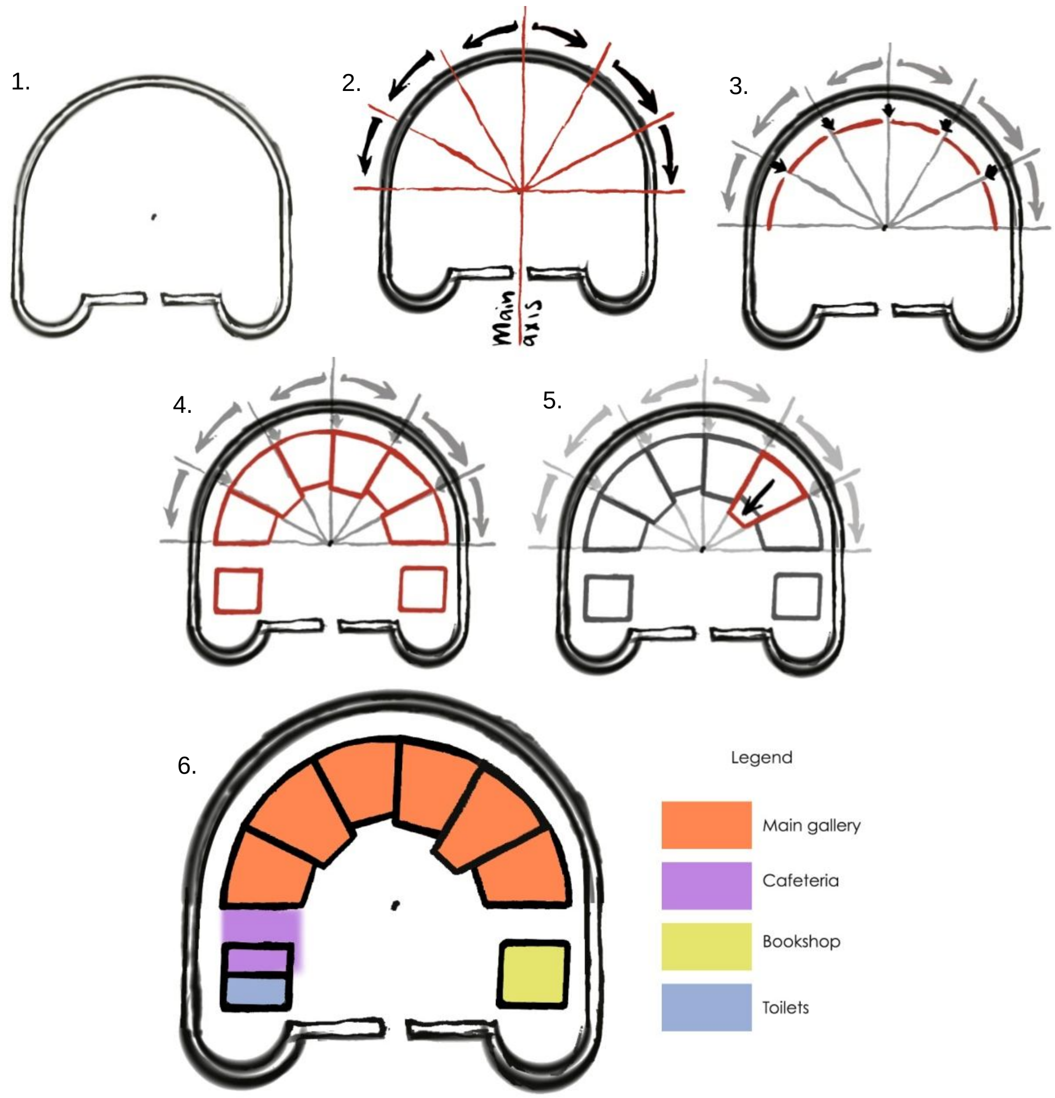


Figure 5.54, Development of the design proposal

According to figure 5.54, number 1 shows the existing Castle's brick wall;

Number 2, represents the transformation of main geometrical axis into 6 directions;

Number 3, shows the detachment of the new structure from the historical wall;

Number 4, shows our proposal. Wall's directions follow geometrical transformation, represented in previous drawings;

Number 5, in order to emphasize the main entrance's volume of our gallery – we extrude the chosen box;

Number 6 represents functional content of our proposal.

Balloon frame structure serves different block's functions:

- Main gallery comprising of 6 boxes: lobby and information centre, world and civilization's section, video art room, modern painting and sculpture section, common special exhibition.
- Open café with kitchen and toilets
- Bookshop.

5.11.2.1. Design Inspiration

Rainscreen siding for the façade of gallery boxes of main gallery was inspired by the LOBLOLLY HOUSE by KIERANTIMBERLAKE – project, that aimstoputthefocusonthenatural environmentandalsoreflectsan environmentalethic.


Figure 5.55 & 5.56, Loblolly house by Kierantimberlake, Taylors Island,

Design for gallery entrances was inspired by project Sill to Sill, Hackney City Farm. The large sash windows were the first salvaged materials re-adapted as apertures along the timber façade.


Figure 5.57 & 5.58, Sill to Sill, Hackney City Farm, London, UK

5.11.3. Pool design

The main goal of having pool is to

- take an advantage of having precipitations inside the castle
- create a space for visitors where they can relax, having their lunch (also brought from the cafeteria nearby)

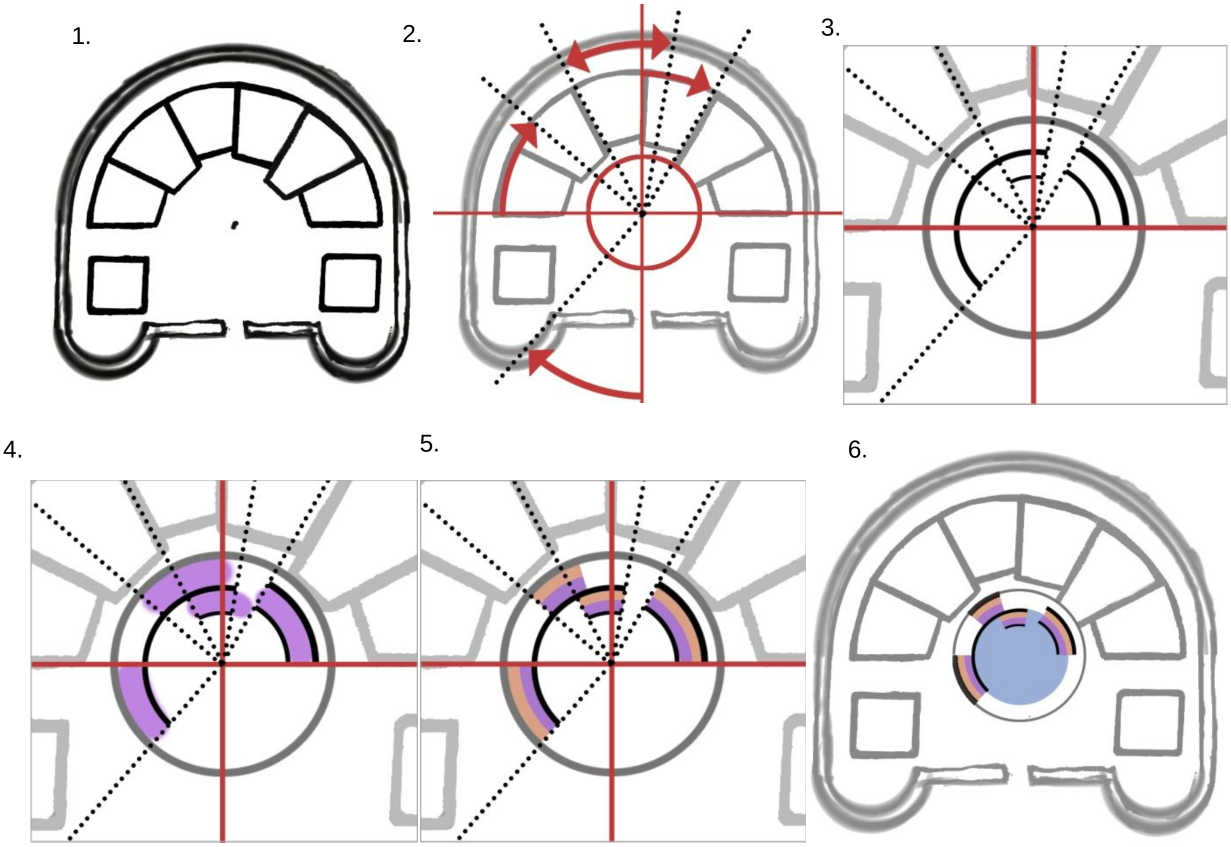


Figure 5.59, Designing process of the inner garden

According to figure 5.59, number 1 shows our proposal for the Castle gallery;

Number 2 and 3, represent secondary axis (in dotes), which are results of main axis’s rotation (in red color);

Number 4 and 5, represent the creation of platforms (violet color) inside the pool with benches (orange color) installed on them;

And number 6, shows the final result.

Shallow pool with the deepness of 50 cm is filled with water, which is coming from the hole in the tent. It is covered with tiles of local natural stone. The main supporting column of the tensile roof is installed on the elevated platform in the center of the pool. Round-shaped platforms with places for rest are inside the pool and on the different water level.

5.11.4. Accessibility (Horizontal + Vertical) and Main Entrances

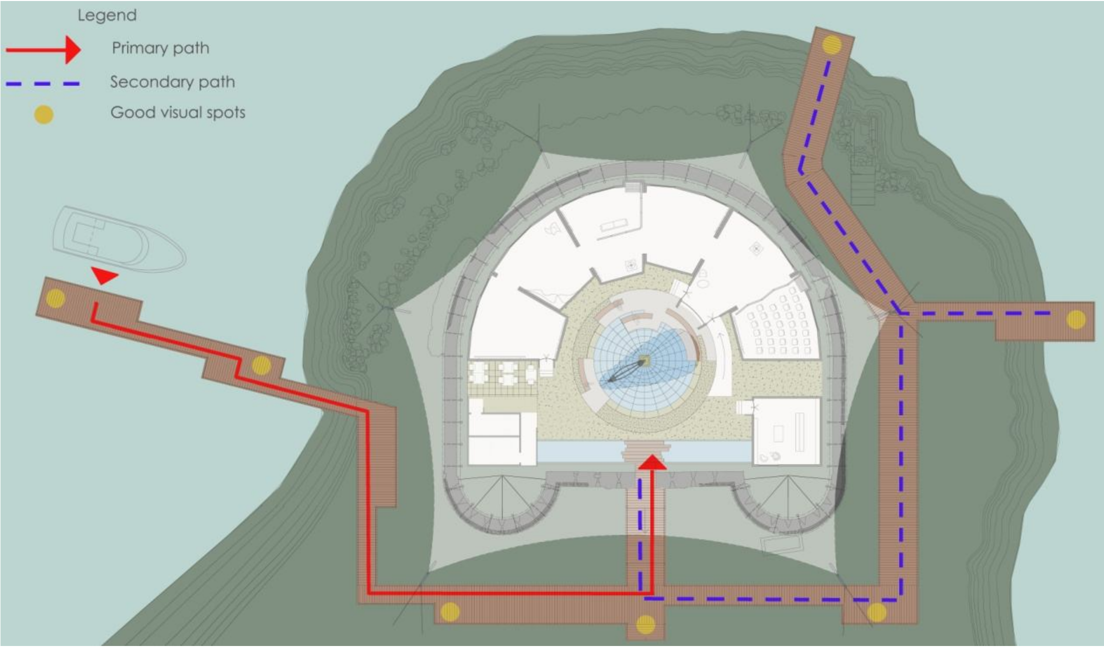


Figure 5.60, Accessibility diagram

The castle can be reached by boat. Arriving to the main pier, tourists follow the pier's path, which has the dynamic shape and width variation 4 or 2 meters. It is made in order to create platforms with good visual views of the Castle.

Primary path leads to the Castle's entrance. Secondary path gives the opportunity to walk around the Castle.

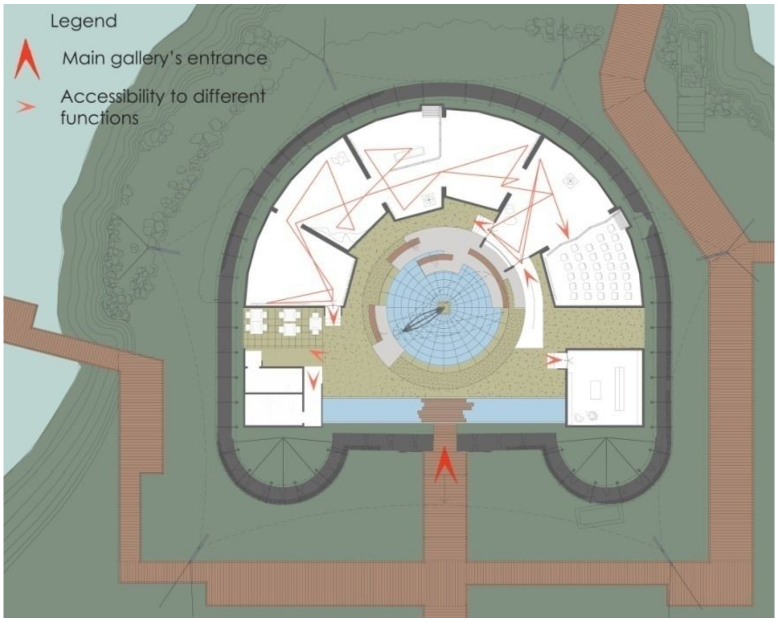


Figure 5.61, Circulation diagram

Entering the historical building, visitors find themselves in the completely different from the outside environment. Passing through the shallow pool, which lies along the entrance's wall, on their right the white curved ramp leading to the main gallery's entrance could be found. After enjoying the exhibition, visitors could exit from the door next to the cafeteria and toilets. The bookshop is on the opposite side of the central pool.

5.11.5. Form Blow-Up

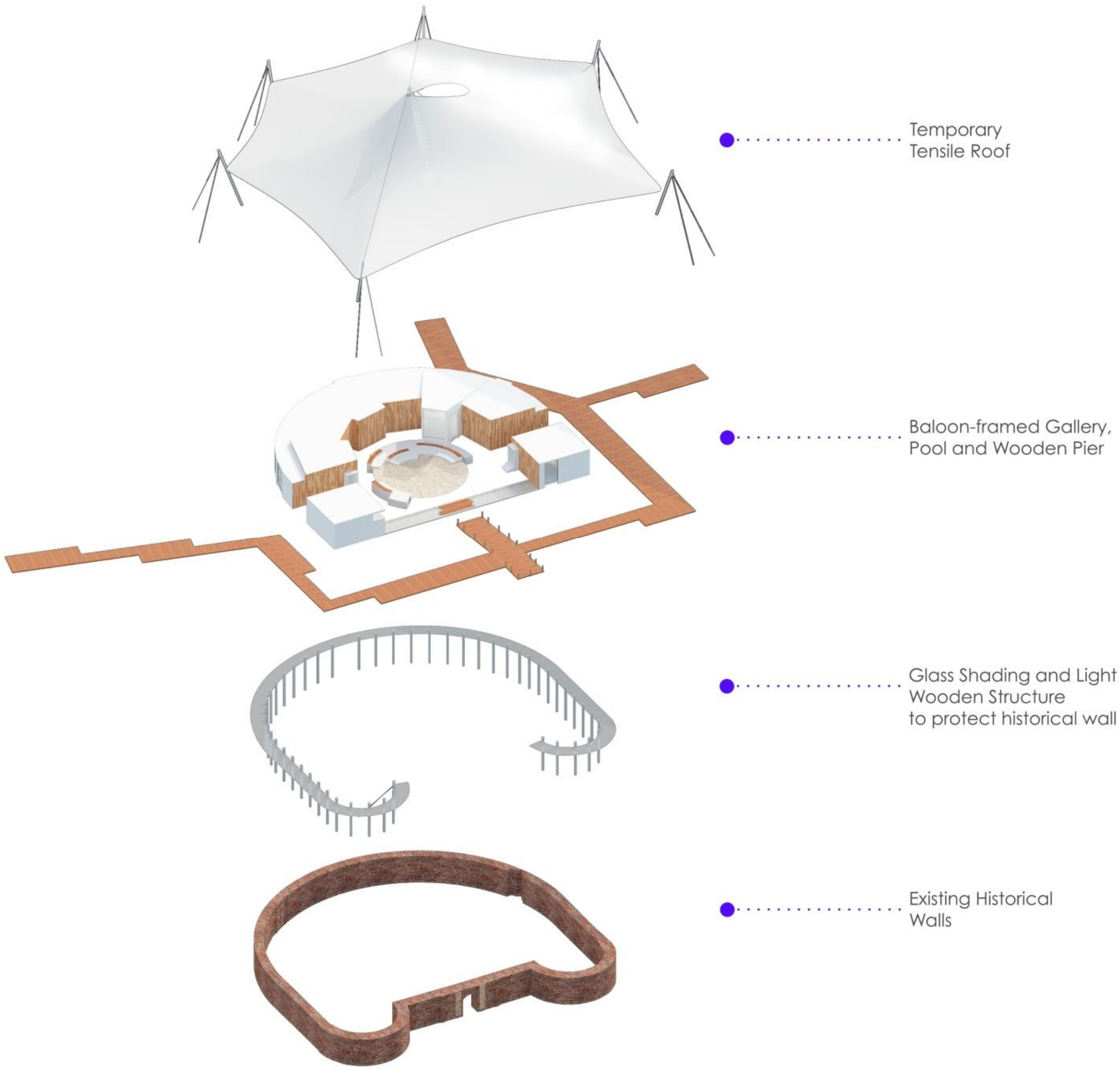


Figure 5.62, Study of the whole structure morphology

The expansion diagram is showing the hierarchy of main construction elements of the proposal.

The existing historical wall of the Castle is protected on the top with glass shading and light wooden structure. The inclined wall is anchored to ground by using cable.

Balloon framed gallery boxes are installed inside the Castle, together with pool and pier structure outside.

The new and historical buildings are covered with tensile roof.

5.12. Design Proposal

5.12.1. Layout

Passing through the shallow water basin in the entrance of the Castle, arriving to the inner courtyard, visiting the gallery and the cafe with seats outside and view of the garden, all give the feeling of peace, tranquility, safety and satisfaction to the visitor. Art gallery with its light but permanent structure will be a place for temporary exhibitions and workshops.

5.12.2. Plan

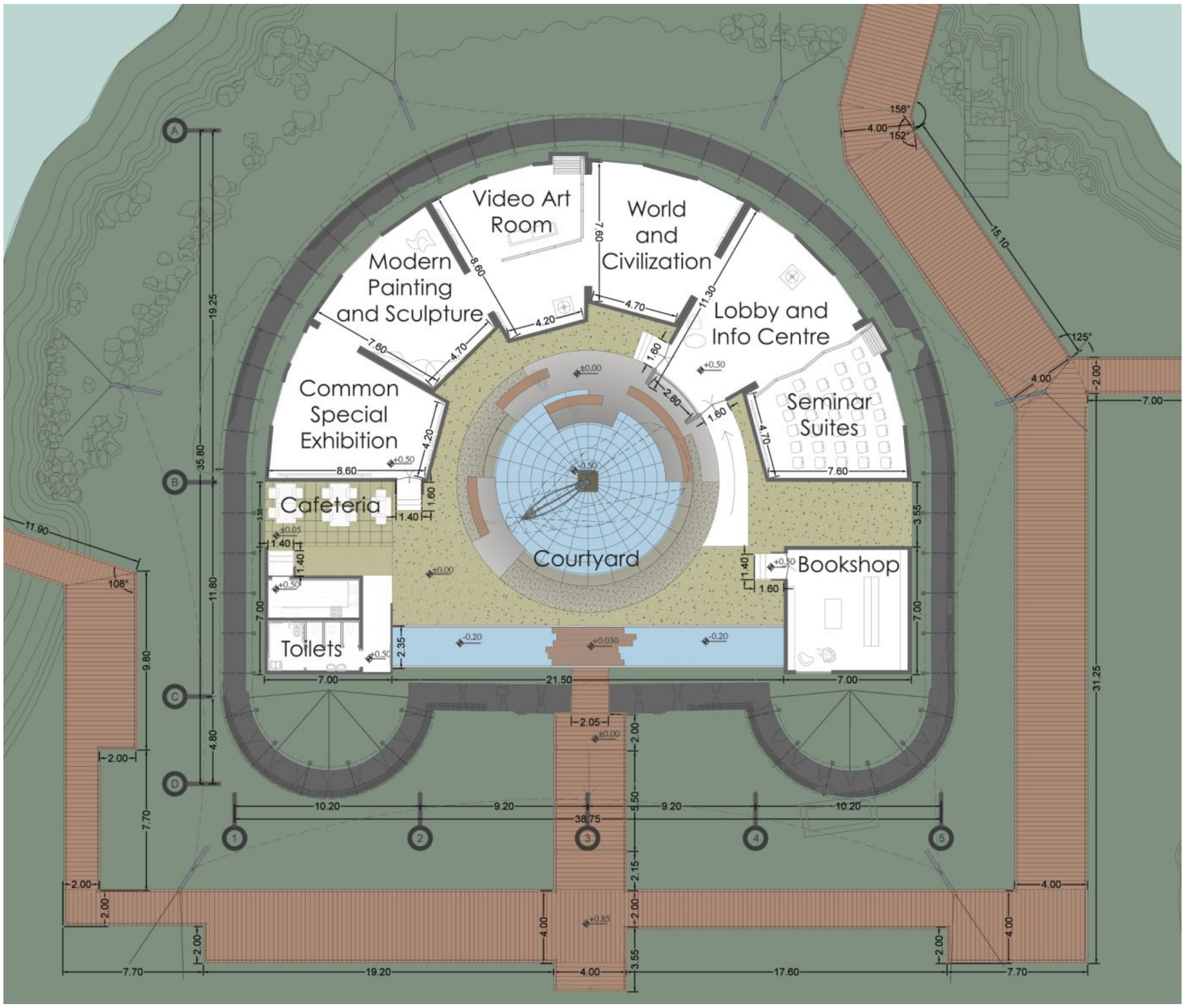
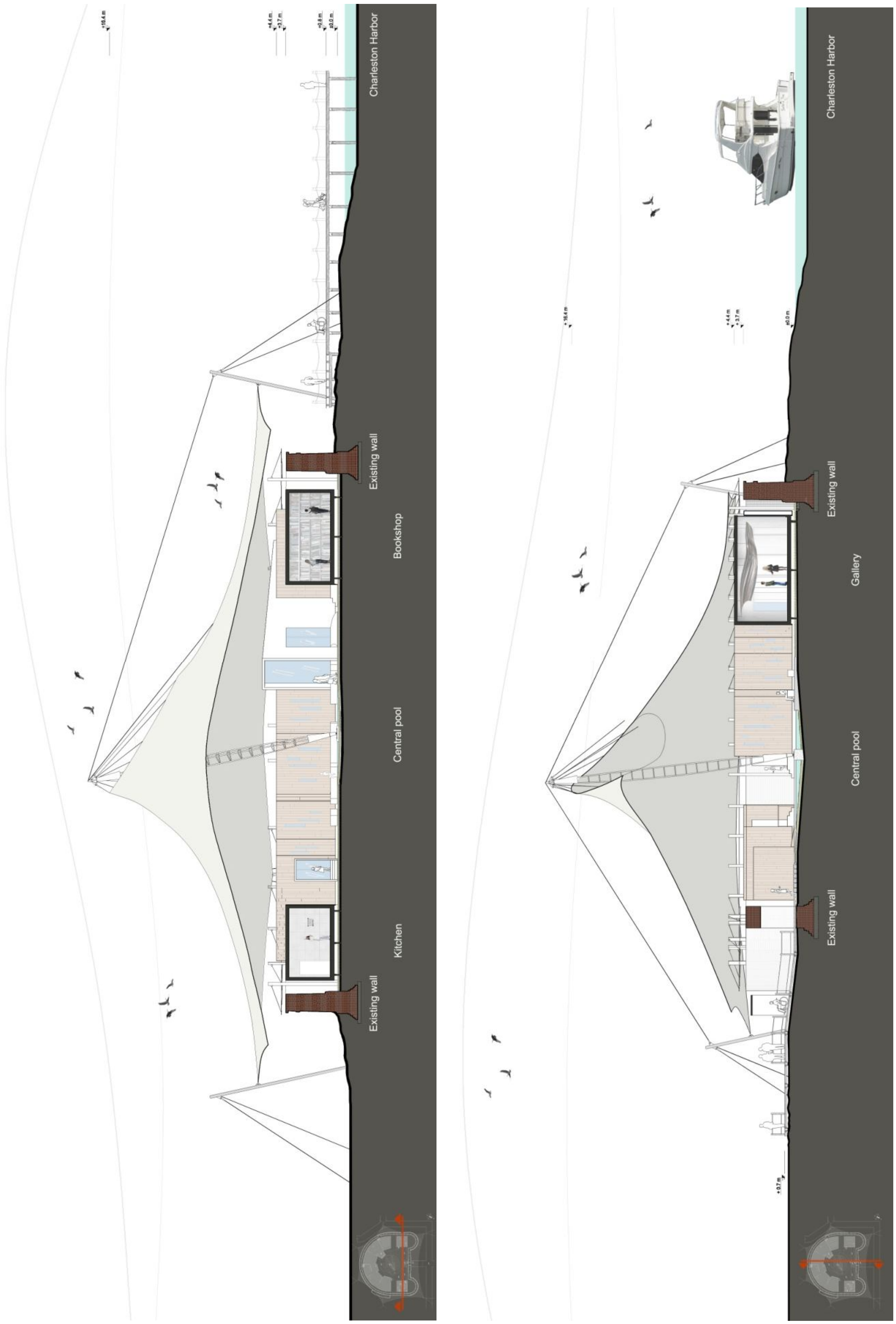


Figure 5.63, Final proposed plan

5.12.3. Sections & Elevations

Figure 5.64, Northern elevation

Figure 5.65, Western elevation



Figures 5.66 & 5.67, Castle's sections

5.12.4. Final Results

In this part of Architectural proposal for the Castle Pinckney will be shown most attractive views demonstrating exterior and inner garden, and solution for the interior of gallery.

Figures 5.68, Bird's view

5.13. Perspective Analysis

5.13.1. Exterior Views of the Castle

Figures 5.69, View to the entrance of the Castle

Figures 5.70, View from Charleston's waterfront

Figures 5.71, View from the approaching boat

Figures 5.72, View from the approaching boat- Night view

5.13.2. Inner Space of the Castle Pinckney

Inner garden of the Castle comprises of several main elements: central pool, that people are facing ones entering the Castle, inclined column, supporting the tensile roof, main entrance block to the gallery

Central pool is filled with shallow water, reflecting the facades of gallery and inclined column. That has not only structural role, but also aesthetical one, becoming a kind of sculpture. This place is a center of communication and relaxation for visitors, thanks to the seats, arranged around the pool.

Cafeteria – is another common place, employed to serve simple dishes, already prepared in Charleston and supplied to the Shutes Folly Island.

Figures 5.73, View from the Castle's entrance into the inner space

Figure 5.74, View to the pool and cafeteria

Figure 5.75, Inner space

5.13.3. Interior of the Gallery

For interior space we use white painting in order to make it light and spacious. This design is flexible to different kind of exhibitions, working as a neutral background. Narrow windows to the inner garden make ‘play’ of natural light which could be a part of exhibition, providing interesting visual effects during day time. On the opposite side, transparent surface makes strong relation between new light and temporary structure and heavy historical brick wall. These two completely different in their characteristics materials are working in harmony, avoiding contradiction.

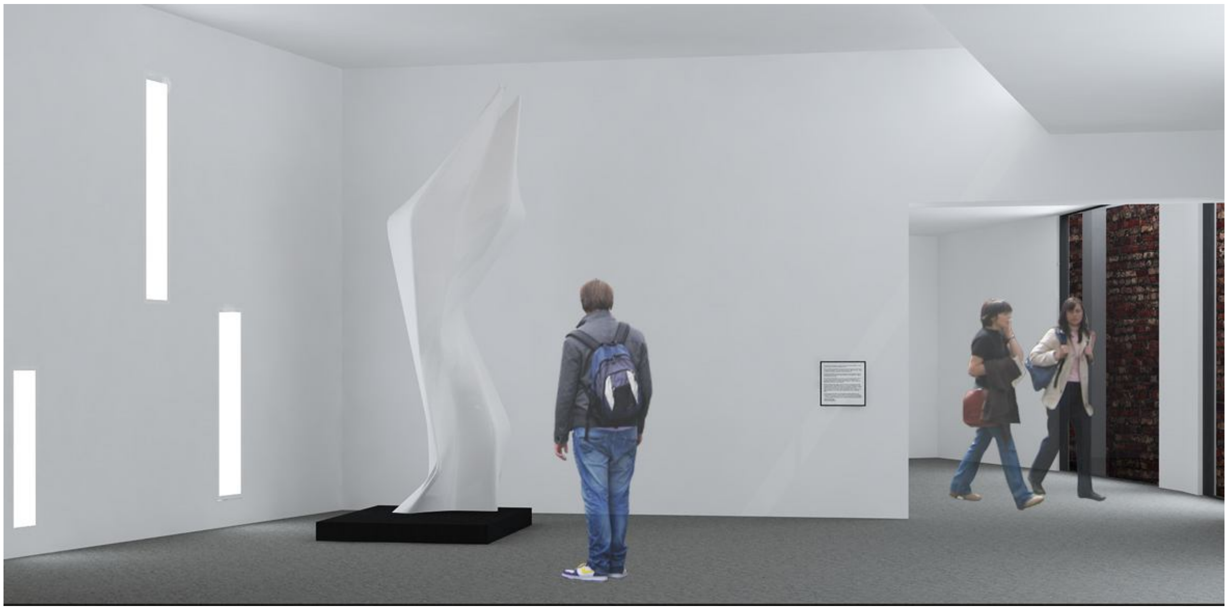


Figure 5.76, Interior exposition

Figure 5.77, Video Projection as the part of exposition

During nighttime the gallery's hall could be used for video installations. Photos or video could be projected on the brick wall. Overlapping historical pattern and modern art could be a special attraction for artists and visitors to exhibit and to enjoy respectively.

5.14. New Use of Reclaimed Gallery's Parts

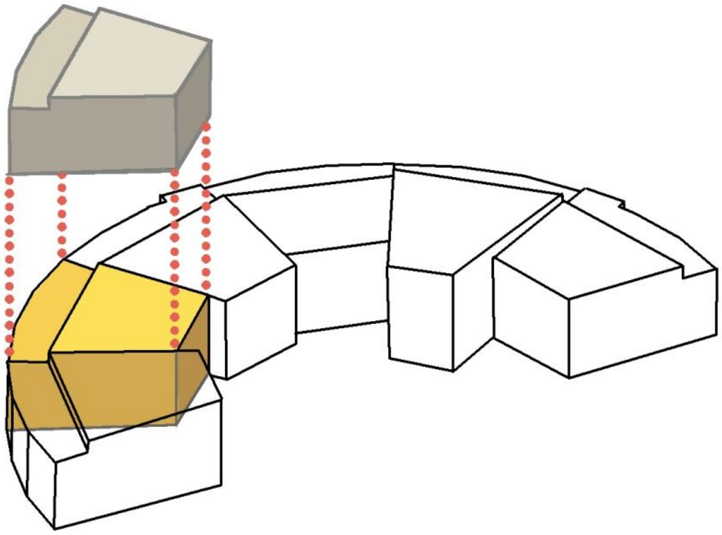


Figure 5.78, showing the extraction of gallery's sector

Our design proposal for the Castle aimed to create a temporary structure, which could be dismantled if the purpose and function of place changes. Balloon-framed gallery can be easily restored and each of 6 boxes could be placed within Charleston city representing new different functions such as bar, or bookshop or ticket office etc.

Figure 5.79, Beach bar as an example of new use for reclaimed box

5.15. Materials

Materials, chosen for the project of Castle's area are compatible with the materials of the context we were working, we tried to choose typical materials of Charleston. In order to give a feeling of a complex project, together with Pier, we are using similar materials for our architectural ensemble.

In accordance to our observation of Charleston building materials, our chose has been made in favor of these types, listed below:

- Stone

Color of stone, used for the central pool, was inspired by the existing paving, used in the Charleston. It is a local material and could be easily transported to the Castle for the construction works.

Figure 5.80, Stone paving found in the city

Figure 5.81, Stone paving, chosen for our project

- White siding

This material has been chosen for the restaurant design, as it was mentioned before. In order to give the feeling of relation between two parts of our project, we apply the same material for Main entrance of a new gallery, designed inside the Castle.

Figure 5.82, White siding on the façade of Charleston's building

- Wooden panels

Wood is used for the decoration of gallery's boxes inside the Castle. This is a local material, which means it's available within the construction area and also compatible with our design.
Rainscreen siding is made of wood with slightly different color tone. This solution was inspired by the existing paving, found in Charleston, which difference in color is the trace of time.

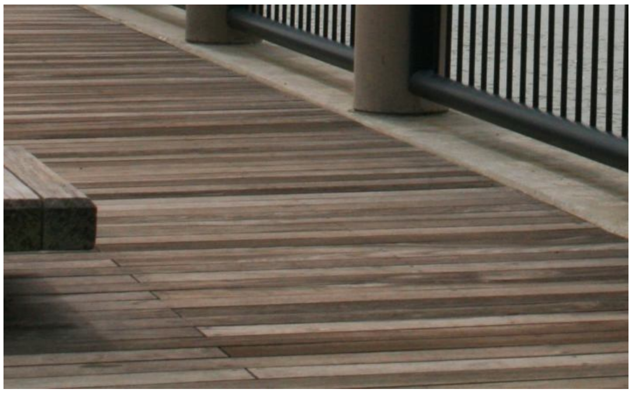


Figure 5.83 and 5.84, Wooden paving in Charleston and our application for the rainscreen siding

- Gravel

Gravel is used in the inner space of the Castle in order to absorb precipitations and keep comfort humidity level.

Figure 5.85, Gravel, used inside the Castle

Chapter 6

Structure

Chapter 6

Structure

6.1. Tensile Roof for Castle Pinckney

Fabric structures vary vastly from other forms of building materials. Their light weight and versatility in shape and structure provides a unique range of dynamic and exciting three dimensional options. These shapes can create remarkable landmarks which catch attentions. Fabric architecture covers not only complex tensioned membrane structures through fabric engineering but also beautiful and unique fabric sculptures and shade structures.

Having long been used in tent structures, where guy ropes provide tension to the fabric that allows the tent structure to withstand heavy loads, these principles were only adapted to create tensile membrane structures in the last few decades.

One of the major advantages of fabric architecture is that very few components are required to create a structure and the ingenuity and scale of fabric structures is as boundless as the extensive freedom fabric membrane structures offer for imaginative designs.

6.1.1. Basic Theories

Membrane structures rely on double curvature to resist imposed loads efficiently. Imagine a flat piece of fabric. An imposed download of snow can only be resisted by tension in the horizontal fibers – a bit like making the catenary cables on a suspension bridge horizontal and expecting them to still carry the weight of the road deck.

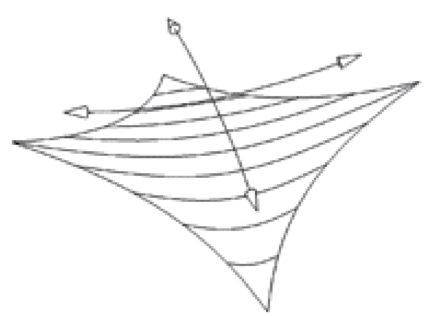


Figure 6.1, a classic Hyperbolic Parabolic

In Fig 6.1, a classic Hyperbolic Parabolic, any point on the membrane surface can be restrained by the corner points. The two high points pick up any downloads and the two low points resist the wind uplift.
The flatter the fabric, ie the smaller height difference between the high and low points, the greater the resultant loads will be at the corners.

Inflatable fabric structures are synclasticforms where constant air pressure balloons the fabric into shapes also exhibiting double curvature. *Anticlastic* forms like the Hyperbolic Parabolichave *opposing* curvatures.Other common anticlasticforms are the cone (Fig 6.2) and the arch form (Fig 6.3).

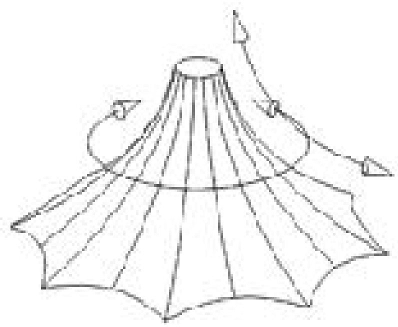


Figure 6.2, a cone

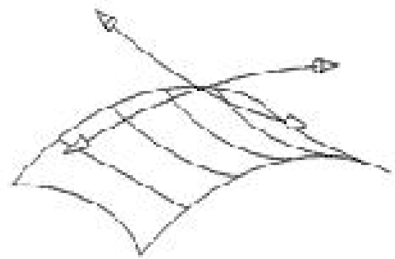


Figure 6.3, arch form

Nearly all tensile canopies are derived from either one or a combination of these three shapes. The surface of the membrane adopts a similar kind of characteristic double curvature.

The creative challenge to designers is to explore the development of striking new forms, which satisfy the structural requirements of the membrane's surface. Developing new shapes of push-up elements and varying the design of the perimeter connections enables dramatic variation in the appearance of a structure.

Membrane forms can be soft or spiky, rotund or leaf-like. They are frequently a combination of these forms. Pre-Stressis the tensile forces introduced in the canopy during erection. The shape of a membrane surface is determined by the ratio of pre-stress in the two principal directions of curvature. Absolute values of pre-stress are calculated to be sufficient to keep all parts of the membrane in tension under any load case.

Any imposed live load will be carried by redistributing the stresses within the membrane. If this results in any section going into compression, i.e. going slack, then creases will appear. Similarly if the pre-stress is not high enough a snow load could cause ponding.

The Figure 6.4 shows mainand typical detailing of the tensile structure:

1- Anchorage
2- Stiff edges
3- Flexible edges
4- Corner details
5- High-point

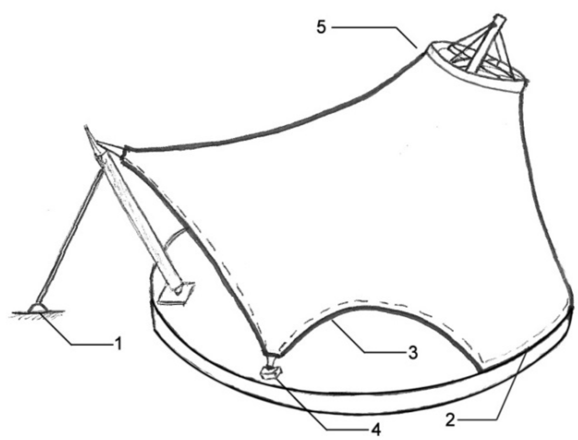
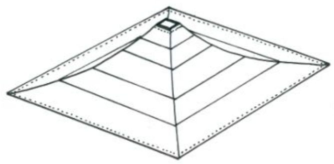
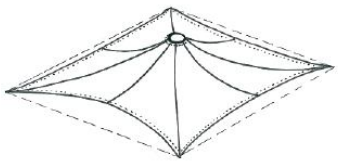
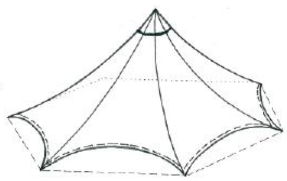


Figure 6.4, Canopy parts

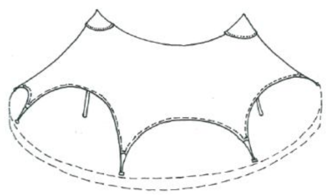
In the table belowwe can see a comparison between different structural alternatives:



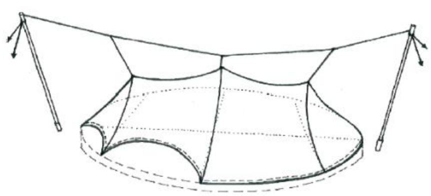

Most generic symmetrical membrane, supported with an inner mast - high pointed membrane.

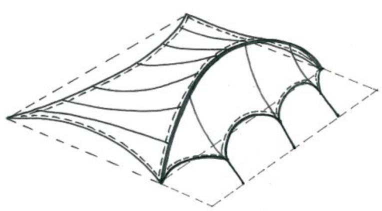
Most generic symmetrical membrane over a polygon, supported with an inner mast .



Generic, high pointed structure with multiple mast support and flexible edges.

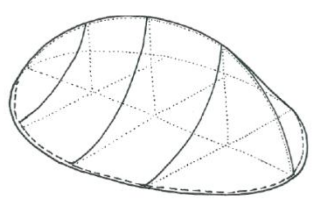


Membrane supported from outside, with flexible and stiff edges.

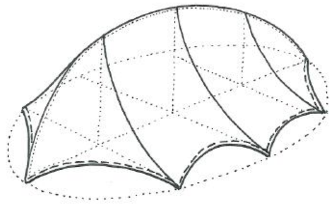


Structure stretched on an arch, combined with flexible edges.

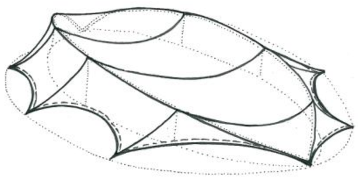
Combined geometry with surface stretched on arch, with flexible and stiff linear edges.



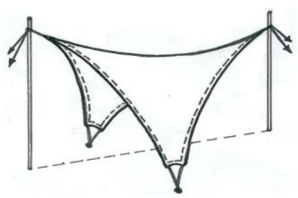
Membrane stretched over an ellipsis on an arch, combined with stiff edges. Hard to erect.



Membrane stretched over an ellipsis on an arch, combined with flexible edges.



Membrane stretched over an ellipsis on two arches, combined with flexible edges and stiff corners.



Hyperbolic parabolic membrane stretched by the corner rings. It is used quite commonly, often at smaller constructions.

6.1.2. Simple Statics of Tensioned Surface Structures

The stresses and forces imposed to a tensile structure could be the subject of a PhD thesis but our point is an engineering collection and a preliminary design philosophy.

Generally for tensile structures in every point of the surface there are two different stress-systems present. First one is the so-called meridian force-system, which connects the mast and the anchorage in the case of membrane and does not allow the construction to lift. The other one is the ring-bearing, which connects the horizontal stress-components of the neighboring elements. As we can see in Figure 6.5&6.6, the canopy without these stresses would elongate in the meridian direction and would split. These two systems are always exist in each point but will slightly change in the corner: the ring-stresses are hitting the wire ropes and the meridian forces are having another angle to the ropes than ninety degree.

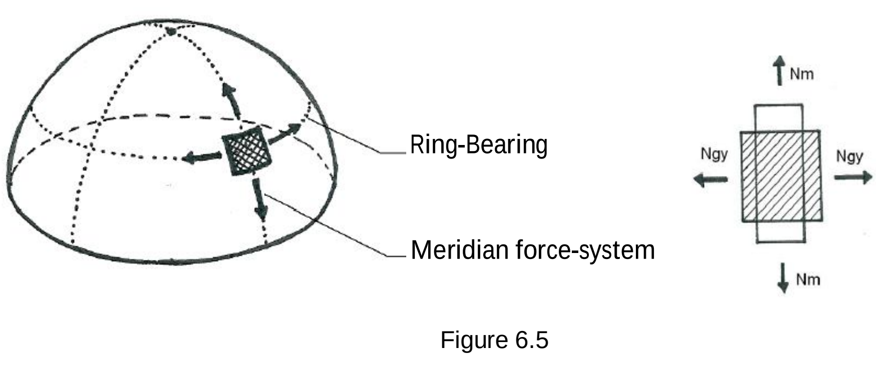


Figure 6.5

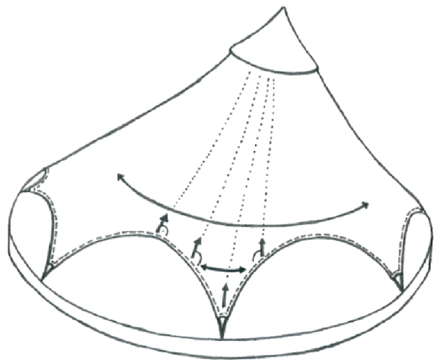
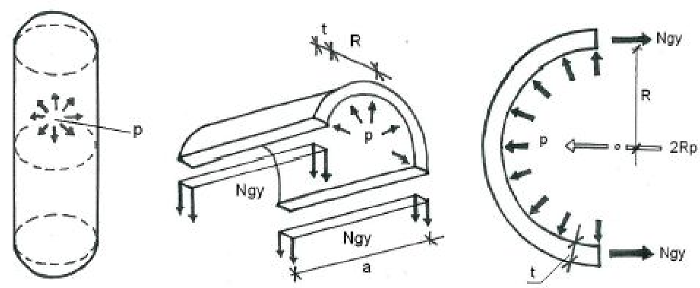
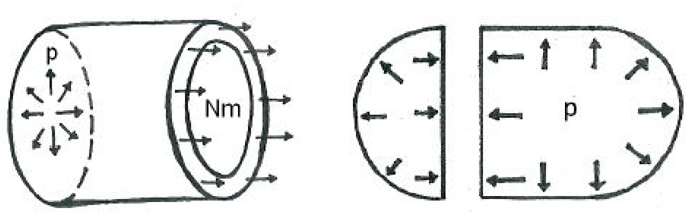


Figure 6.6

In fact we can balance these stresses with pulling forces at the endings of the curved ropes, bases on the formula of Mariotte. For better understanding we expresses how a tube loaded with inner pressure can stay balanced:

$$\sigma gy = \frac{PR}{t} \quad \sigma m = \frac{PR}{2t}$$





With developing this formula you can explain the membrane stresses in the surface even in three-dimensional cases.

(a.b.q=P)

Q=q.b

b=r.α

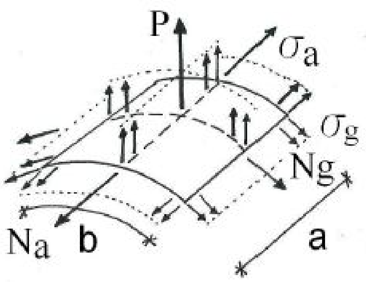
Q=2.σg.(sin(α/2))

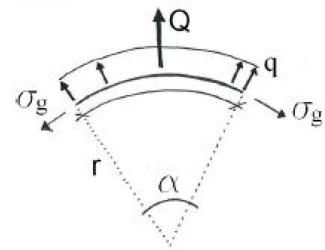
$$r.q = \frac{2\sigma g.(sin\left(\frac{\alpha}{2}\right))}{\alpha}$$

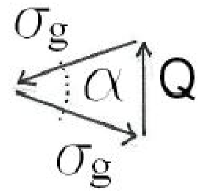
If the piece of the surface is infinitely small then:

$$Sin\ (\alpha) \sim \alpha$$

$$q = \frac{\alpha g}{r}$$



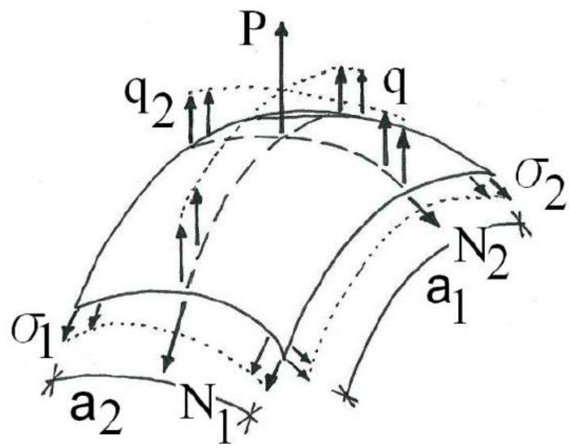


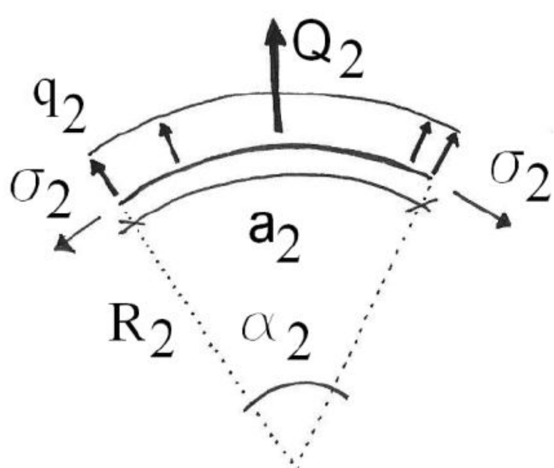


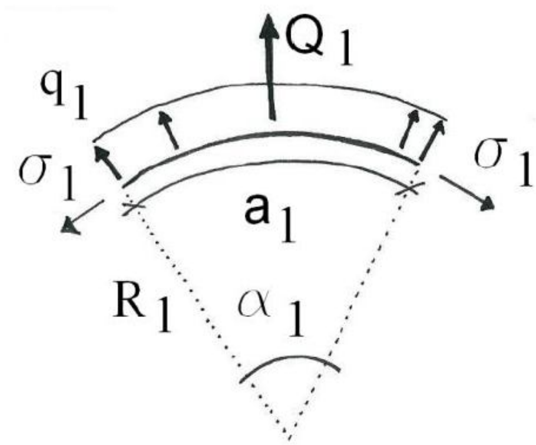
N2=σ2.a1

N1=σ1.a2

The goal at this type of structures is to ensure stability without the loads; however at these formulas we can understand the static behavior of the surface.







On the left side drawing bellow you can see the meridian-force-system alone. When we split it into components, we can see a force-system parallel to the axis of the rope, which tries to pull up the membrane from the corner, so it would split in the middle. And we can see the other stress system perpendicular to the axis, which tries to pull the membrane together and causing creases and excess in the fabric. Important is, according to the Mariotte formula, the forces perpendicular to the rope can be supported in the form of pulling forces. The parallel forces must be supported with other fittings. Even a small skin friction is working here, but we cannot base the designing on it.

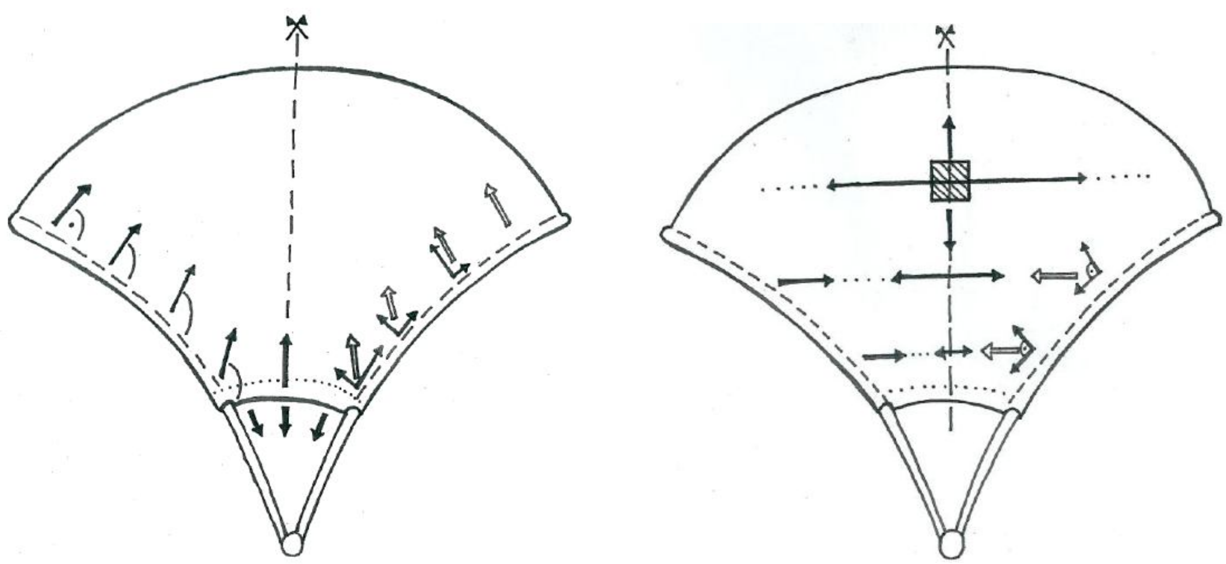


Figure 6.7, On the left, meridian-force-system alone.

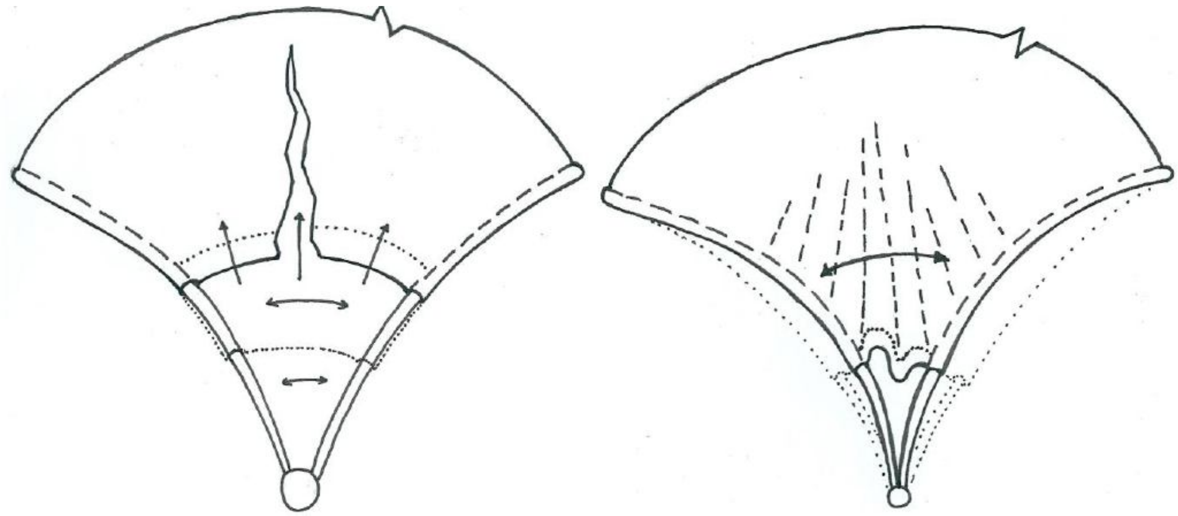


Figure 6.8, Tearing mechanism

6.1.3. Material

A coated structural fabric consists of a woven base cloth stabilized and protected by a coating on both sides. The base cloth consists of warp threads running the length of the roll and weft threads running across the width.

Figure 6.9

A mesh fabric is a coated cloth with spacing between the thread bundles. With some meshes for interiors use the threads are coated before weaving.

Tensile fabrics have different range of tensile strength, mainly depends on their type. Later we discuss about their range and numbers. But the important is that a factor of safety of 6 on a maximum design loads is used select a cloth although this may be reduced if the circumstances are well understood i.e. if the maximum strength of the membrane is 10 tons/linear meter the maximum permissible load would be 1.7 tons/meter, and the typical pre-stress load would be 150-350kg/meter.

All fabrics will stretch under load although some exhibit different characteristics as a function of time. A structural fabric would not creep under load once it has reached full pretension. Each roll of fabric is tested in a biaxial rig to measure the stretch in both thread directions at load ratios derived from the form generation computer model. These figures would then be used as compensation percentages to be factored into the patterning software. The canopy is manufactured undersize so that when installed to its final dimensions it tensions out correctly.

6.1.3.1. Coated Fabrics

Most commonly used in the construction of tensile structures is PVC (Poly Vinyl Chloride) coated polyester, chosen not only for its excellent strength, flexibility and translucency but also its impressive design life of 15 to 20 years. It is mainly used for exterior canopies and its wide range of colors. The PVC coating contains additives that include UV stabilizers, fire retardants, coloring and anti-fungicide. Also widely used for permanent exterior structures is the strong, durable and low maintenance PTFE (Poly Tetra FluroEthlene) (Teflon) Coated Glass Cloth, which has more than 30 years design life. It is completely chemically inert and resistant to moisture and micro-organisms as well as having good self-cleaning properties. Alternatively, Gore Tenara can be used. This is a UV resistant, chemically inert, easy to maintain, versatile tensile membrane to include in any architectural fabric project. It is essentially a wieldable form of PTFE offering strength, flexibility and longevity as well as unrivalled aesthetics and its high crease resistance makes it effective for demountable and retractable canopies. A good example of a Tenara structure is the Eat Street project at the Westfield Shopping Centre in London.

Figure 6.10, Westfield Shopping Centre in London

A new technology for tensile fabrics is PVC or PTFE coated with titanium dioxide (TiO^2). Photocatalytic membrane structures which utilse TiO^2 coating technology promise enduring beauty, translucence and 'as new' appearances for many years. When PVC or PTFE membranes are coated with titanium dioxide (TiO^2) photo-catalyst, they inherit self-cleaning properties that's far superior to conventional membranes. It's called the Photocatalytic Decomposition Process, a self-cleaning action that occurs as the TiO^2 causes any organic matter (stain or pollutant) to decompose through simple oxidation. The residue does not adhere to the surface and is washed away by water or rain. Known as the Photocatalytic Hydrophilic Process, The 'sheeting' action of water across the surface assures no unsightly streaking is left behind due to beading. PTFE and PVC membranes treated with TiO^2 also remove significant volumes of nitrogen oxide (NOx) from the atmosphere. In this reaction between TiO^2 and the air, both nitrogen and sulphur oxide from vehicle exhaust emissions, are decomposed to produce cleaner, purer air; at a rate of 1.2g (NOx)/1000m2/h.*

6.1.3.2. PVC Coated Fabric with TiO2

This is a combination of standard base cloth material coated in PVC, with TiO2 photocatalytic treatment added to the fabric surface. Due to the oxidation decomposition and highly hydrophilic nature caused by the TiO2 dirt can be easily washed off.

As this photocatalytic coating lasts as long as the membrane life, the fabric structure will always appear clean and new. Also its high heat reflectivity avoids solar heat gain inside the building or structure.

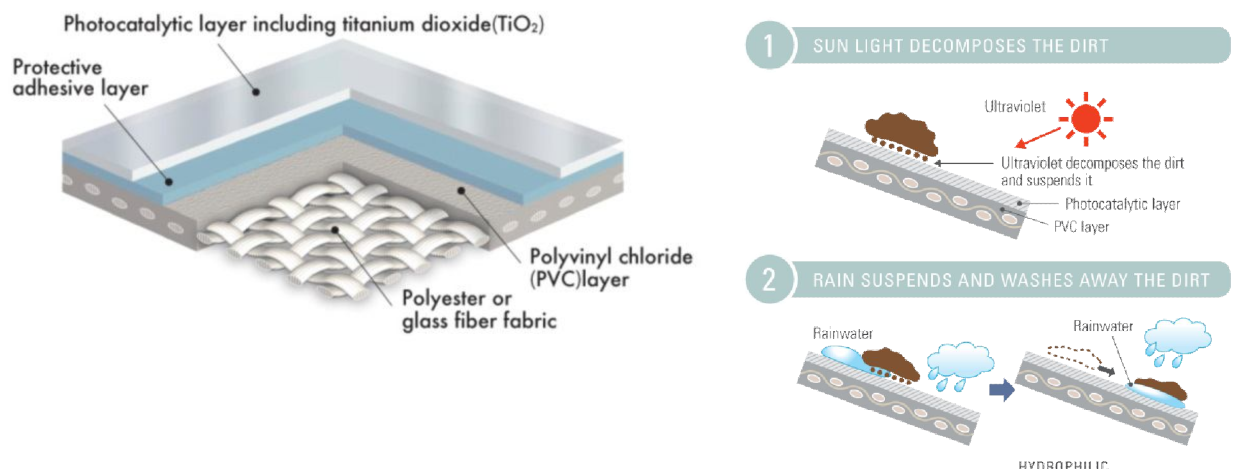


Figure 6.11, PVC coated (TiO2)

6.1.3.3. PTFE Coated Fabric with TiO2

This is a combination of standard base cloth material coated in PTFE, with TiO2 photocatalytic treatment added to the fabric surface. It demonstrates PTFE membrane's own strength and light transmission while removing dirt and contaminants by oxidation decomposition, the result of a photocatalytic action. The antifouling property also works on the vertical surface where traditional fabrics often show dirt and contaminants. The TiO2 photocatalytic effect lasts as long as the membrane life.

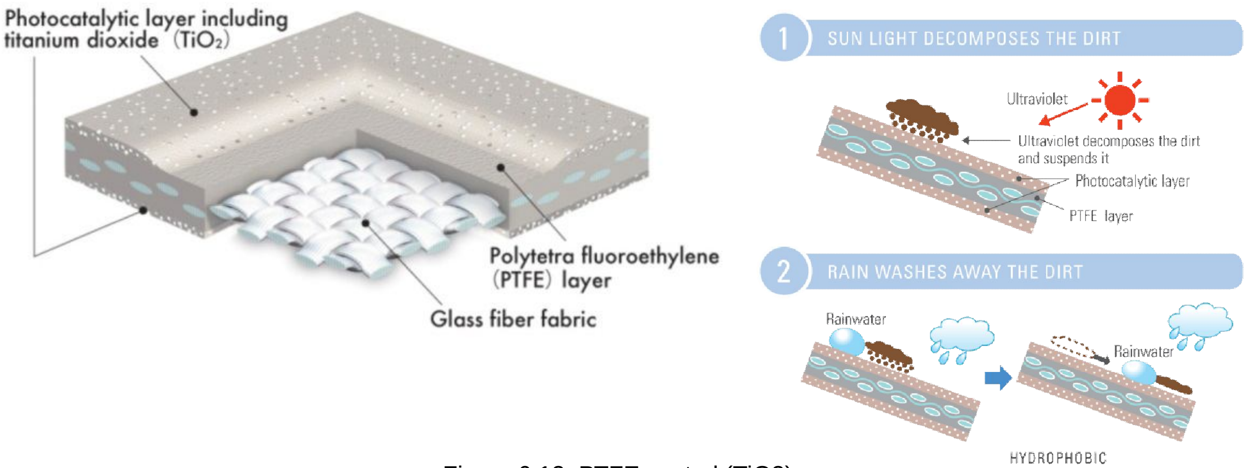


Figure 6.12, PTFE coated (TiO2)

Rain or water washes the broken down dirt, mold and build-up off the fabric. Nitrate ions from the dirt then washes onto the landscape, fertilizing flowers, plants and trees.

Because the Ti02 coating renders fabrics self-cleaning, we eliminate the need for cleaning products; reduce on-going cleaning costs and the associated carbon footprint.

Ti02 is the most widely used white pigment because of its brightness and very high refractive index. When used as a coating, PVC and PTFE fabrics remain white and bright for the lifetime of the fabric.

6.1.4. Detailing of Tensile

6.1.4.1. Load Resolution

Canopies fall into two main types, those that transfer tensile loads into adjoining structures and those containing the tensile loads within their own frame. The first type may generate large lateral loads which may result in the need for additional in existing structures.

Likewise a typical ‘lightweight’ canopy with masts and cable tie backs to the ground level will generally need large concrete foundations or screw anchors to resist the tensile loads. As part of the preliminary design process a provisional load analysis derived from a computer modal will give typical loads directions and size of the design loads.

6.1.4.2. Boundary Detail

The boundary of the membrane into two categories:

Curved/scalloped edge- This generally consists of a cable slid through a pocket on the edge of the membrane. In larger canopies webbing belts are added parallel to the edge to take out the shear loads. An alternative detail used for PTFE canopies is to an exposed cable connected to the clamped edge of the membrane by series of stainless steel link plates.

Straight edge- The membrane would have a bead/keder edge formed by sealing a flexible PVC rod in a small pocket. This can then be trapped behind an aluminum clamp plate bolted directly onto the structural steel work or slid into an aluminum luff track extrusion.

Canopies can be tensioned by hydraulically jacking the mast with the base being housed in a sand pot or the mast can be extended with a telescopic section.

Corners can be pulled out with rigging screws, U bolts or by the shortening the perimeter mast ties back cables. Individual scallops can be tensioned by shortening the edge cable where the swaged studs connect onto the membrane plate. A very common detail is to pull panels into parallel luff tracks and tension by drawing out the corner plate that slides inside the luff track.

From yurts made of animal skins, to NASA space suits made of PTFE, fabrics have evolved and changed over time and yet all suffer from some form of environmental build-up.

6.1.4.3. Applications

Ti02 fabric can be applied on any of our structures. Transportation venues, sports & leisure centers, business parks, healthcare and education sectors will all benefit from this environmentally positive new fabric. Where it makes the most sense is in areas where the localized pollution level is at its greatest – such as cities.

PTFE (Teflon) coated glass cloth has become established as the highest quality architectural membrane for tensile structures. The material was developed by DuPont in the 1960’s and has been used for structures since the early 1970’s. The original 25 year design lifespan of the material has already been exceeded by the earliest structures, and present day expectations are for 30-50 year lifespans.

PVC coated polyester had been used as an economical alternative to PTFE cloth, typically achieving savings of £50-£70 per m2 on construction costs. The lifespan of PVC coated polyester is typically 15-20 years.

Each fabric is available in various strength ranges, and selection is primarily an engineering-based decision. The thicker fabrics have tensile strength of 150kN per meter, while the lighter grade fabrics have tensile strength of 75-100kN per meter. The heavier grade fabrics have light transmission rates of 9-12 %, while the lighter grade fabrics allow 14-16%

6.1.4.4. Wind

A frequently asked question is if 'tensile' are suitable for windy sites. The answer is yes as long as the canopy is properly engineered. In the computer analysis of the different load cases wind uplift is usually as great as the live snow load. Detailing of the fittings and surrounding structure needs to take into account the maximum deflection of the membrane as well as loads. A factor of safety between 4 and 6 is then used to select the fabric weight. Boundary details need to accommodate the oscillations that may be generated at the canopy extremities. In these extreme circumstances an annual re-tension/maintenance check is recommended. Usually designing for heavy snow loads requires more care as we have greater risk of melt water ponding but according to the general climate of Charleston city we don't face such situation as the probability of snow fall is so low. Any how the profiles would generally need to be steeper and spans smaller.

6.1.4.5. Sun

PVC fabrics incorporate UV stabilizers which protect color fastness and base cloth slowing the rate of degradation; however in high UV lifespan will be reduced. After 20 years the PVC will lose its flexibility and will become more brittle. In areas of high humidity regular cleaning will reduce the risk of mold growth on the surface of the fabric causing permanent staining. For design life over 10 years in areas of high UV, pollution or humidity, PTFE/glass becomes a better option.

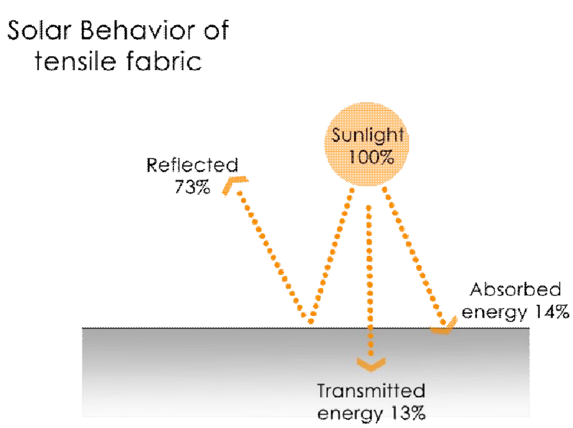


Figure 6.13

6.1.4.6. Fire

The fire performance of a membrane depends on the base cloth and the seam details. All membranes will de-tension under high temperatures. The speed will start peeling apart at around 100°c. At 250°c the PVC membrane will melt back from the heat source creating vent holes for heat and smoke. PVC has fire retardants in the coating so that if self-extinguishes when the flame source is removed and therefore would not produce flaming droplets. With PTFE fabric the glass base cloth withstands temperatures up to 1000°c and the openings are limited to failed seams which would part at approximately 270°c.

The net effect in a fire can be quite beneficial as most canopy designs form a smoke reservoir which may well allow sufficient time for escape, and when sufficiently hot self-venting will occur through a failed seam. Critical steelwork should be supported so that partial failure of a damaged roof will not cause collapse of the structure.

The design should consider smoke generated by the membrane used. PTFE fabric used internally may require sprinkler systems or mechanical extraction to reduce toxic fume production at temperatures over 400°c.

6.1.4.7. Thermal Insulation

A single layer of either PVC/polyester or PTFE/glass with a typical weight of around 1200gm/m^2 has a U Value of approximately 4.5 W/m^2k. In this respect it is very similar to glass so that a twin skin with a 200mm air gap will give a U Value of 2.6 W/m^2k. By suspending a quilt in the air gap we can get down to a U Value to meet any building code requirements, but we obviously lose the some of the benefits of translucency. As in our case the tensile roof will be just a protection of the courtyard and gallery underneath which will be installed with a considerable gap, there is no need to consider the thermal insulation of the canopy.

6.1.4.8. Condensation

As we would expect in some cold weather conditions condensation is likely to occur with roofs covering a sealed heated space. The design of the roof gradients and edge detailing can minimize any problems. Ventilation can obviously reduce the risk but if more control is required then it would be necessary to incorporate a second skin and possibly additional thermal quilt. Control of the air flow in the air gap is recommended to get the best environmental control. A sealed gap is best in winter for insulation and good air flow in the summer will help cooling. The design of roofs especially conic forms can make use of the passive stack effect ventilation with fans or louvers used to enhance the performance if required.

6.1.4.9. Acoustics

As lightweight material with limited mass, PTFE fabric roofs are acoustically relatively transparent, but provide a degree of absorption and noise attenuation. The inclusion of an insulted layer greatly enhances the acoustic attention of a tensile roof, particularly for mid to high frequency noise sources. This is particularly helpful for lessening the ringing reverberant in din that can affect courtyard and atrium environments.

A single fabric membrane is virtually transparent to low frequency sound due to its low mass. A double skin with an acoustic quilt interlayer will give us the absorption figures required. Reverberation times on the other hand can be very successfully reduced with tensile fabric linings with acoustic quilt behind wither wall mounted or hung on drop wires.

6.1.4.10 Vandalism

Unlike glass or brittle panels fabric is highly resistant to impact damage from blunt objects. It is however susceptible to sharp objects. Small cuts can be repaired with glue-on patches. Larger tears may need specialist repair with portable hot air welders. If an invisible repair is required then the membrane may need to be removed and a replacement panel inserted in the factory. Graffiti solvents may damage the PVC lacquers so should be avoided. PTFE fabrics are highly resistant to abuse as paints won't key to the surface.

The sensible solution is to design out the problem as much as possible but putting the fabric out of reach and details the masts accordingly to minimize the risk of climbing. In vulnerable areas a modular canopy with slide out panels may be a sensible precaution to minimize replacement costs. Some structures such as public bus stops in very exposed sites are probably not ideally suited for membranes. Advantages over overhead glass canopies are that thrown objects tend to bounce off a fabric canopy and health and safety issue of falling glass is largely resolved.

6.1.4.11. Cleaning

PTFE coated glass roofs are extremely low in maintenance due to the cleaning action of rain on the Teflon outer layer. Typically, cleaning is recommended every 2-5 years, depending on the location of the structure and its exposure to environmental pollution. The fabric is sufficiently strong to support a man's weight on its surface, so cleaning simply requires the incorporation of man-safe systems to access the roof surface.

Ideally canopies should be cleaned annually but PTFE/glass fabric would be the preferred option if cleaning is unlikely or impractical. This is because its inherent 'no-stick' surface resists pollutant adhesion and allows rain to clean off most dirt. Raw PVC is readily adhered to by pollutants so all membranes are treated with dirt resistant lacquers or surface foils. Careful cleaning maintains their life and the optimum appearance of the membrane.

Although most architectural fabrics are barely thicker than 1mm, they are immensely strong and with careful engineering, are capable of withstanding forces of many tons, which enables them to endure difficult weather conditions under tension. A typical structural fabric would have a tensile strength of 10 tons in the fill.

6.1.4.12. Life

PTFE is actively bleached by UV light, which had the effect of maintaining a bright white appearance in the long term. The Teflon coating provides a chemically inert layer which resists the buildup of environmental pollution. The material had been extensively tested both in the laboratory and out in the field and no degradation or loss of strength is observed. The material does not become brittle or discolor over time. It is anticipated that the material has a life in excess of 30 years.

6.1.4.13. Weight

Single skin PTFE roofs typically weigh 1.5 kg/m^2, and thermal sandwich roofs typically weigh 3.5kg per m^2.

6.1.4.14. Membrane Panel Size

Tensile membranes can be manufactured to virtually any size and shape up to 1600m2 in a single panel. The membrane is made up from seam welded sections which are laser-cut into precise patterns. PTFE fabric is usually seamed at widths of 1.5m to 2.5m, with virtually no limit in length. Spans exceeding 60m are achievable, although rare, and potentially requiring reinforcement with structural cables. Fabric panels are pre-assembled in controlled factory conditions and packed for deployment in situ. A 200m2 panel will typically weigh approximately 300kg, and may be lifted into position by a modest crane.

6.1.5. Getting Closer to Design, Case Studies

In the following chapter we briefly introduce 3 selected projects. Tensile canopy roof has been used for all these projects to cover and protect a historical site.

6.1.5.1. Case1

Figure 6.14

Location: Oasis located on the western shore of the Dead Sea, Israel

Preserved subject: Remaining of walls and mosaics of the synagogue in EinGedi

Designer: Guggenheim–Bloch Architects, Sircovich–Labaton Structural Engineers

Figure 6.15

Figure 6.16

Connections are simply with steel cables anchored to concrete foundations. Four columns are holding up the roof.

6.1.5.2. Case2

Figure 6.17

Location: Antigua Guatemala, Guatemala

Preserved subject: Remaining of walls

Designer: GrupoTensotec Guatemala

Figure 6.18

Figure 6.19

Several simple cylunder columns hold the canopy structure.During the day and night, due to lightening the roof reflected dofferent colors.

6.1.5.3. Case 3

Figure 6.20

Location: Chepstow Castle

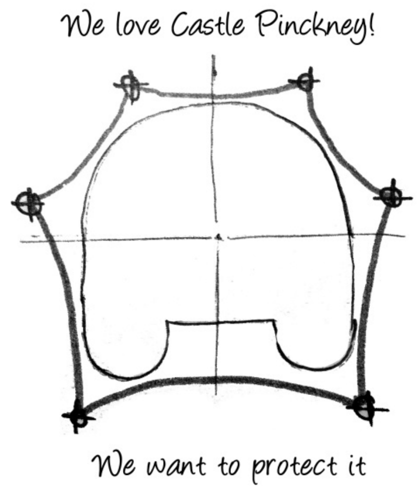
Preserved subject: Remaining of the old castle and court yard

Designer: Hall &Bednarczyk

The canopy is constructed out of white PVC polyester fabric which has a PVDF lacquer coating to protect against microbial and fungal attack, the fabric is also very strong, more durable than some fabrics and is easy to handle which is ideal for a demountable structure. A fabric of this specification should have a life expectancy of anywhere between 25-30 years but as this structure is only being used for 6 weeks a year we would expect it to last longer, obviously the correct maintenance and storage is imperative to prolonging the life of tensile fabric.

Unfortunately the Castle walls as they stood could not withstand the loads which would be imposed by the fabric canopy; steel reinforcements were installed overlaying the existing concrete supports to support the wall and the loads imposed by the canopy. Taking a 'ridge and valley' shape the structure complements the castle grounds and provides an aesthetically pleasing sheltered space designed to accommodate open air theatre.

6.1.6. Design a Proper Roof for Castle Pinckney



After reviewing different roof alternatives, in order to protect Castle Pinckney from destructive elements such as direct sunlight, Pelicans droppings, rainfalls etc. we came up with the idea of a tensile roof which is not only a type of light structure with a great reversibility feature but also can be artistically designed to become a landmark of Shutes folly island. This idea was compatible with the proposed function for castle Pinckney and will protect the art gallery and visitors from sun light and heavy rain falls.

One of the main problems of the Castle is lack of visibility from Charleston city (1.5 Km distance without any visual obstacle). Our tensile roof could be solution to solve this problem, so we decided to make a hole in the middle and raise its elevation up to almost 16 m from the island level.

6.1.6.1. Modeling the Roof with “Form Finder” Software

Form finder assists architects and project planners in the design, planning and cost-effectiveness assessment for the implementation of Lightweight Membrane Structures. This easy to use tool provides solutions from form finding process to material decisions. Advanced features like the instant cost estimation generates a productive dialogue between the client, the architect, the structural planner and the manufacturer influenced by the choice of structural elements. Form finder makes it possible to compare the desired design with existing projects in the Project finder database. Form Finder also serves as the most advanced “Online search engine for Lightweight Membrane Structures.”

6.1.6.2. Modeling the Roof

The process is shown by the pictures bellow:

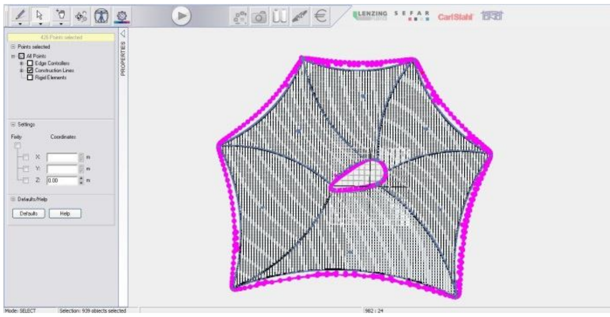


Figure 6.21, Drawing the roof based on boundary taken from 3DsMax

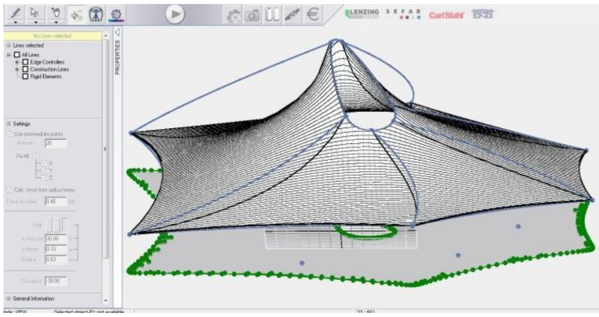


Figure 6.22, Setting the elevation of roof

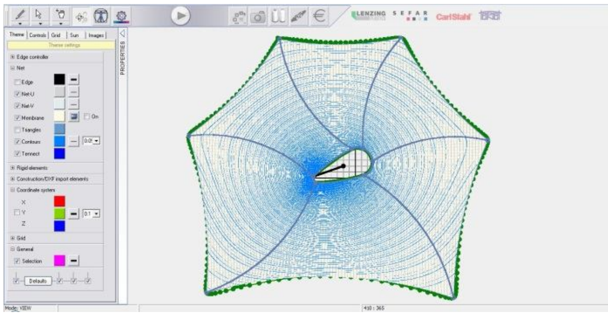


Figure 6.23, Contours

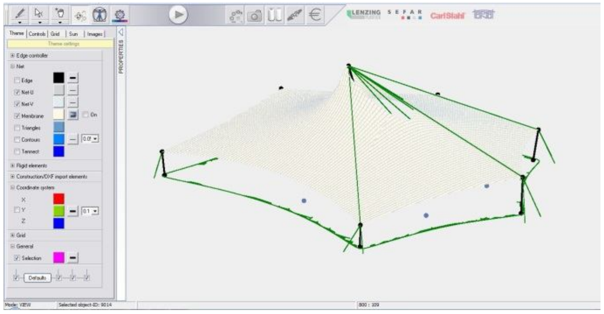


Figure 6.24, Final result

6.1.6.3. Wind & Snow Calculation

Although the exact calculation of tensile structures, especially those which have a unique shape, is not a simple work but by the help of Form Finder software we could be able to run a simple analysis of wind and snow loads imposed to the roof.

The first step of wind calculation was finding the general wind speed for Charleston city. To find the proper value we used Climate Consultant 5.4 software which gave us an annual wind speed diagram for Charleston. The average value for the wind speed in Charleston is not more than 4 m/s which is equal to

15 Km/h. But according to ASCE code Charleston City is located in zone II (Map shown in next page) which means that the 100 MPH ~160 Km/h, should be considered for design. So we run the calculation for both speeds and compare the results.

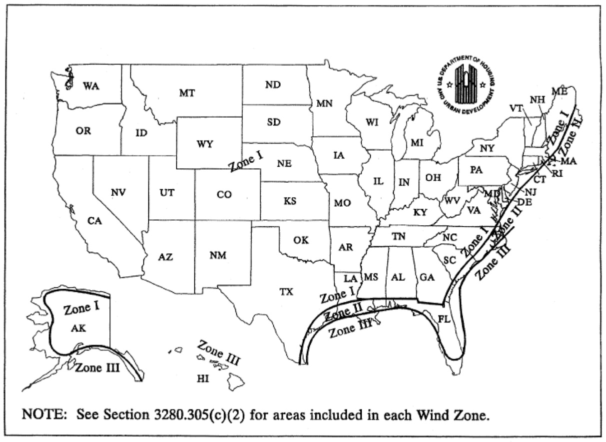


Figure 6.25, Basic Zone map for Wind Speed

WEATHER DATA SUMMARY

LOCATION: CHARLESTON, SC, USA
Latitude/Longitude: 32.9° North, 80.03° West, **Time Zone from Greenwich** -5
Data Source: TMY2-13880 722080 WMO Station Number, **Elevation** 12 m

MONTHLY MEANS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Global Horiz Radiation (Avg Hourly)	338	374	480	530	541	458	513	485	424	452	348	313	Wh/sq.m
Direct Normal Radiation (Avg Hourly)	470	401	460	481	417	340	362	335	328	493	467	394	Wh/sq.m
Diffuse Radiation (Avg Hourly)	118	155	183	192	227	216	238	237	205	158	118	129	Wh/sq.m
Global Horiz Radiation (Max Hourly)	677	782	993	1031	1019	1021	1001	979	926	808	706	600	Wh/sq.m
Direct Normal Radiation (Max Hourly)	996	1024	1029	1007	903	890	886	905	902	926	959	996	Wh/sq.m
Diffuse Radiation (Max Hourly)	341	350	433	508	479	515	554	486	476	388	335	313	Wh/sq.m
Global Horiz Radiation (Avg Daily Total)	2906	3456	4802	5931	6207	5998	6167	5444	4518	4248	3191	2410	Wh/sq.m
Direct Normal Radiation (Avg Daily Total)	4208	3801	4774	5517	4960	4471	4429	3804	3551	4800	4441	3321	Wh/sq.m
Diffuse Radiation (Avg Daily Total)	1050	1468	1870	2188	2653	2851	2899	2703	2223	1531	1097	1028	Wh/sq.m
Global Horiz Illumination (Avg Hourly)	36492	40740	51739	57610	59892	51207	57140	54219	47182	49112	37450	33934	lux
Direct Normal Illumination (Avg Hourly)	44917	38875	44734	46784	39765	31284	33040	29961	29843	47375	44360	37661	lux
Dry Bulb Temperature (Avg Monthly)	7	9	13	17	21	24	26	26	24	18	13	10	degrees C
Dew Point Temperature (Avg Monthly)	0	3	6	10	16	18	20	21	19	12	7	5	degrees C
Relative Humidity (Avg Monthly)	67	69	65	68	77	73	74	77	77	72	71	71	percent
Wind Direction (Monthly Mode)	20	40	200	220	200	40	230	180	20	20	270	190	degrees
Wind Speed (Avg Monthly)	3	4	5	4	3	3	3	3	3	3	3	4	m/s
Ground Temperature (Avg Monthly of 3 Depths)	12	11	11	12	16	19	22	23	22	21	18	14	degrees C

Figure 6.26, A general weather data of Charleston City. Yellow row is the wind speed.

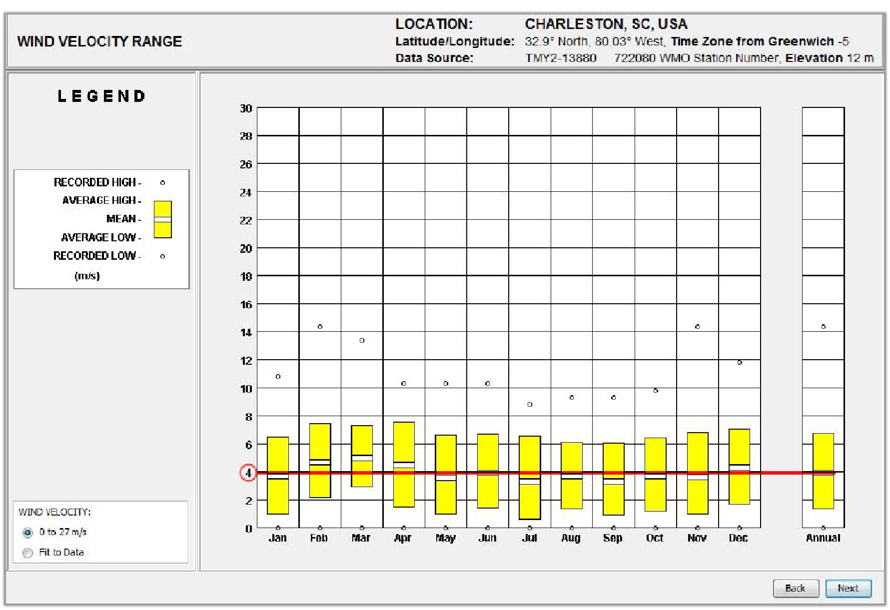


Figure 6.27, Wind velocity range for 12 months and Annual

Form Finder software considers a section of tensile roof with the width of 1 m and calculates the wind and snow loads over that section of roof. We considered the northern part of the roof and inserted the required numbers into the software. This section is shown below:

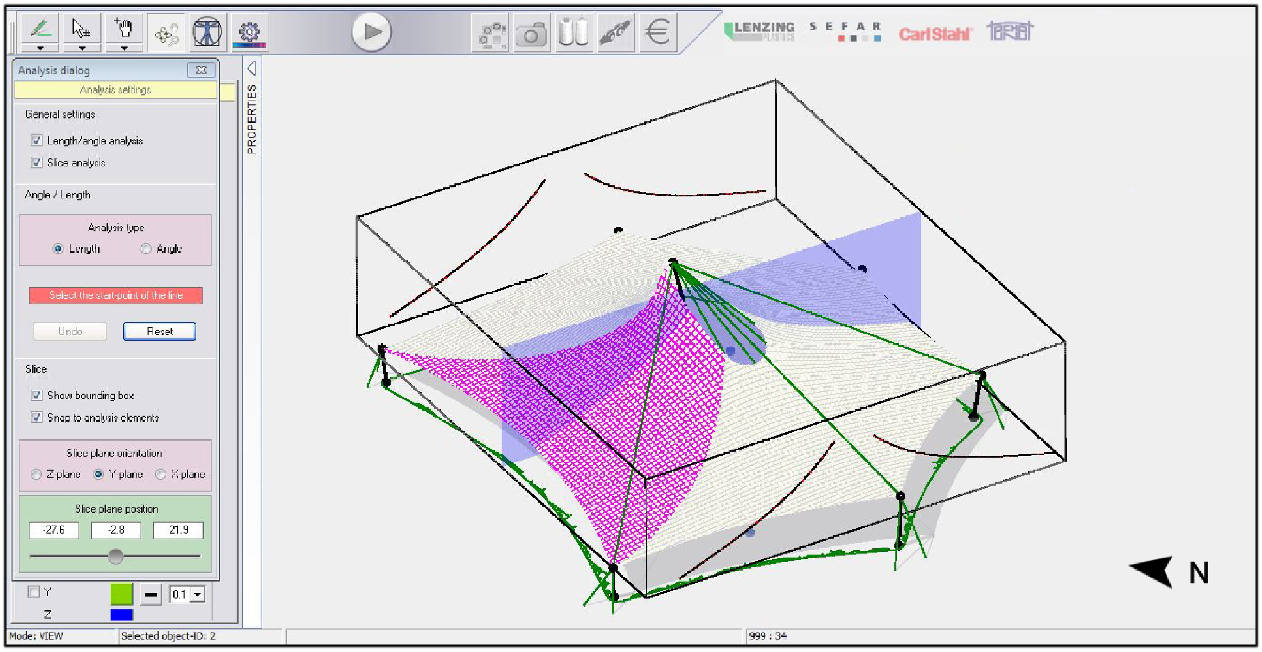


Figure 6.28, Perspective view shows the considered section.

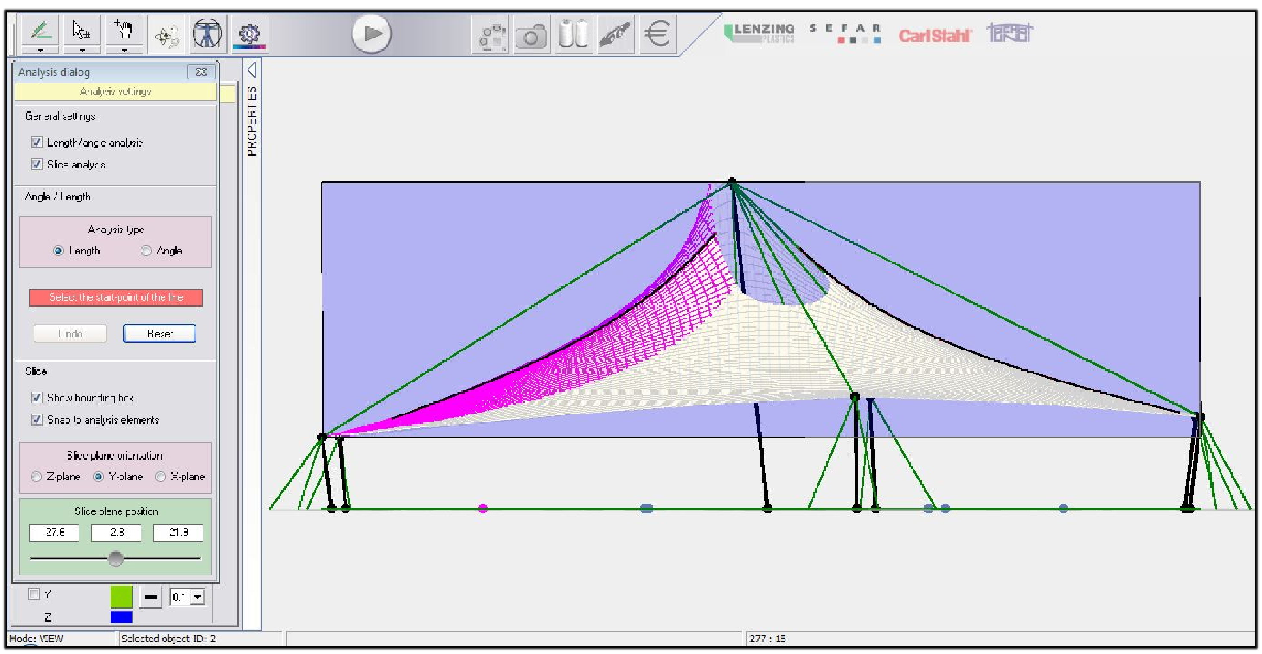


Figure 6.29, Selected section from the pink part is shown

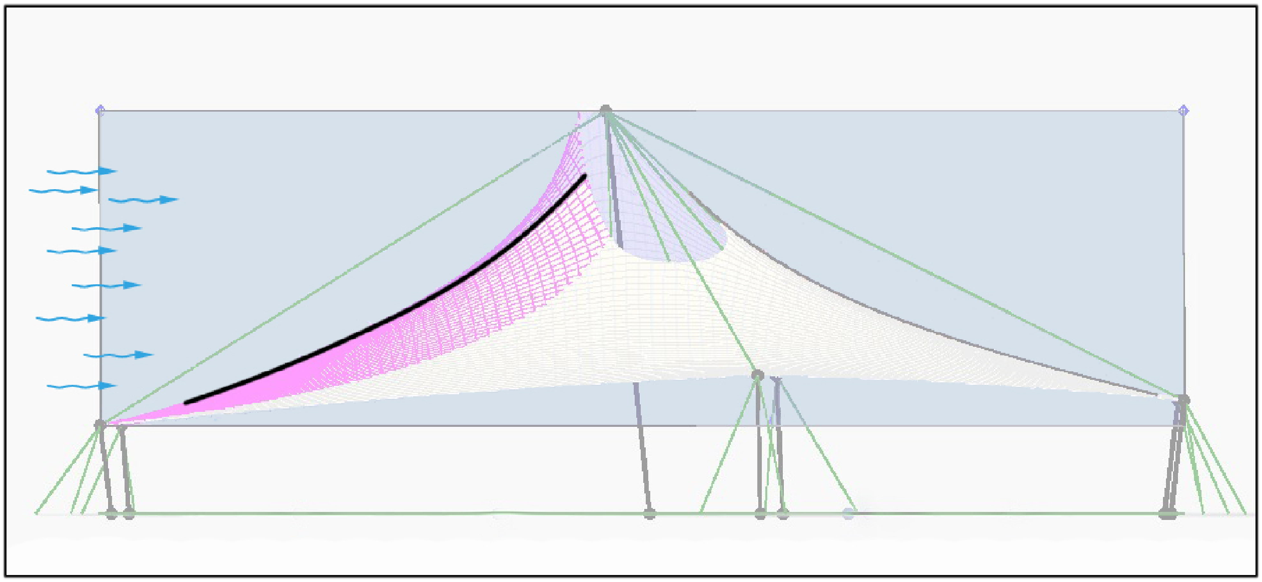
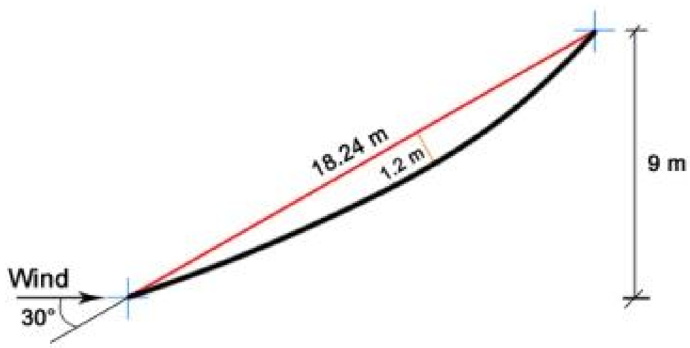


Figure 6.30, Selected section and wind direction

In the figure shown below you can see the selected curve of the northern part of roof and required dimensions:



Inserting data in software:

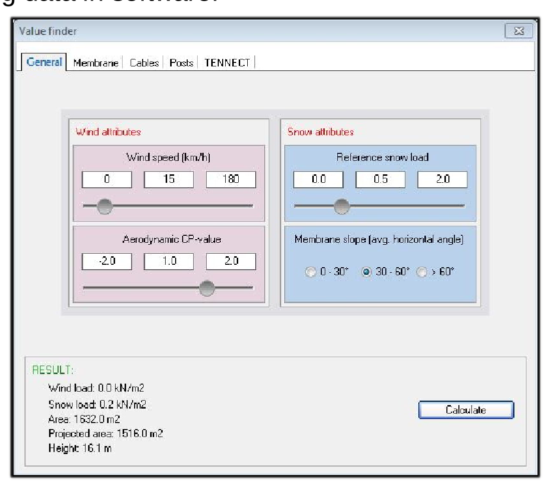


Figure 6.31, Wind speed based on weather data, 15 km/h

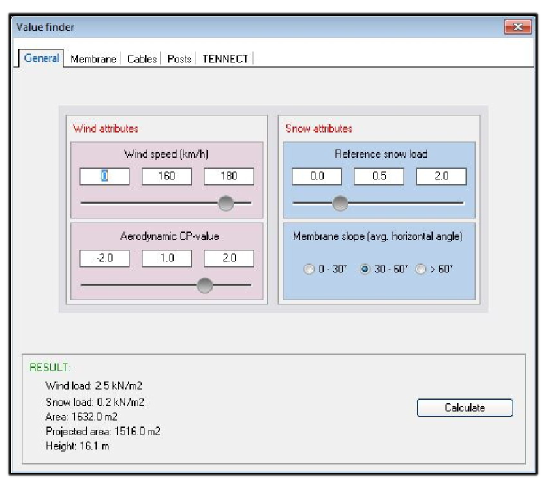


Figure 6.32, Wind speed based on Code, 160 Km/h

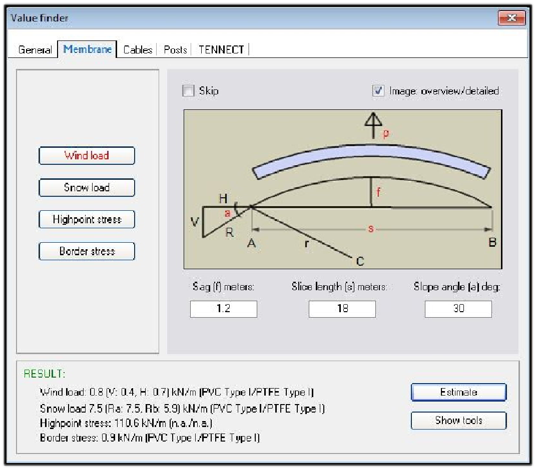


Figure 6.33, Wind speed based on weather data, 15 km/h

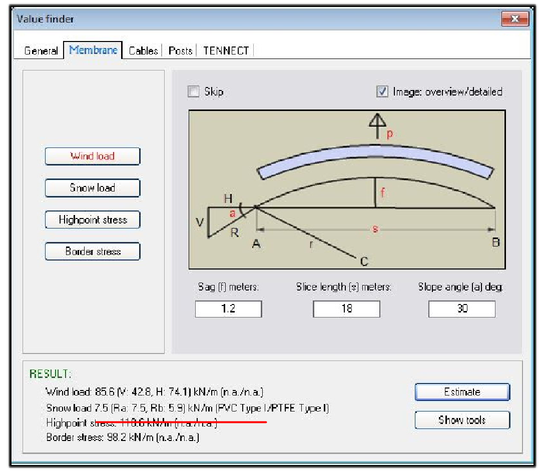


Figure 6.34, Wind speed based on Code, 160 Km/h

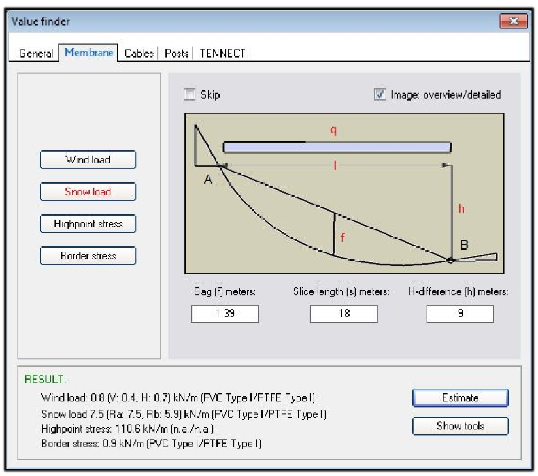


Figure 6.35, Snow calculation, Reference snow load = 0.5

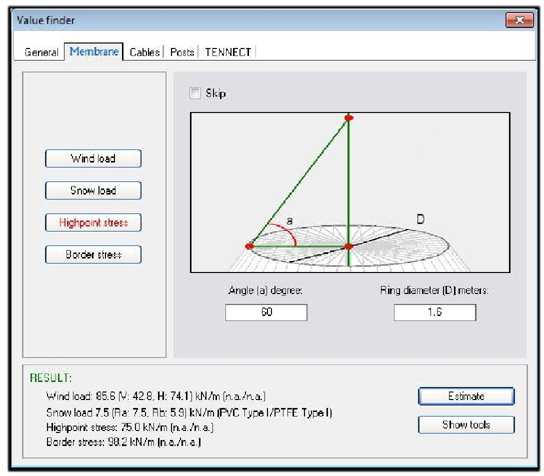


Figure 6.36, Highpoint stress, A ring with 1.6 m diameter is considered foe the highest

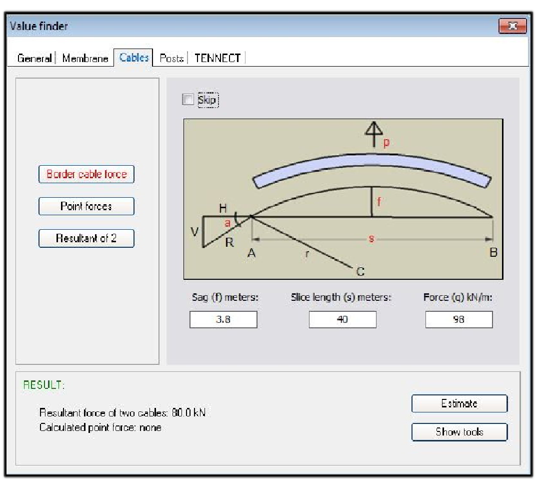


Figure 6.37, Border cable force calculation for the longest curvature between two

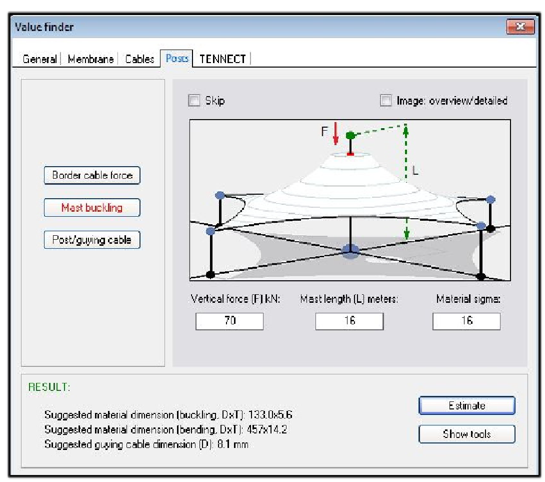


Figure 6.38, Calculation for central Mast, Buckling and Bending

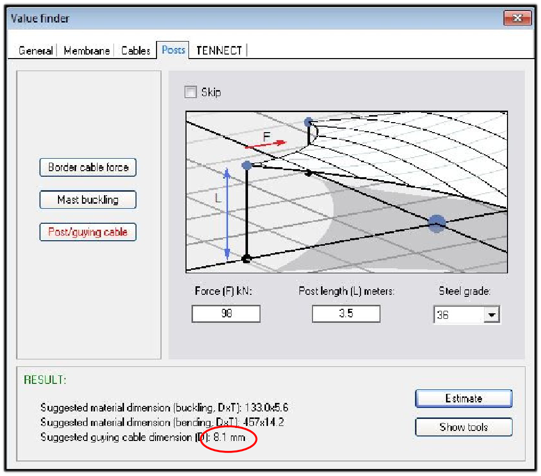


Figure 6.39, Border Cables force calculation

6.1.6.4. Result of Calculation

As we discussed before in the section about materialsthe thicker fabrics have tensile strength of 150kN per meter, while the lighter grade fabrics have tensile strength of 75-100kN per meter.For calculation of allowable stress we should consider a safety factor of 6. If we consider a light grade fabric which has a also a higher light transmittance, the allowable stress will be 100KN/6 = 16,7 . As we can see in the result of Form finder software, for 160 Km/h wind speed, the software couldn’t suggest us a proper fabric. This problem caused by stress imposed by wind whichis nearly 85 KN/m and almost 5 times bigger than allowable stress. In this case the solution will be adding horizontal or vertical cable supports which will decrease the dimension of free curves and unsupported areas in the same section. This solution can be seen in other examples which are shown below:

Figure 6.40, SkySong project – Arizona

FabriTec Structures in conjunction with FTL Design

Architects

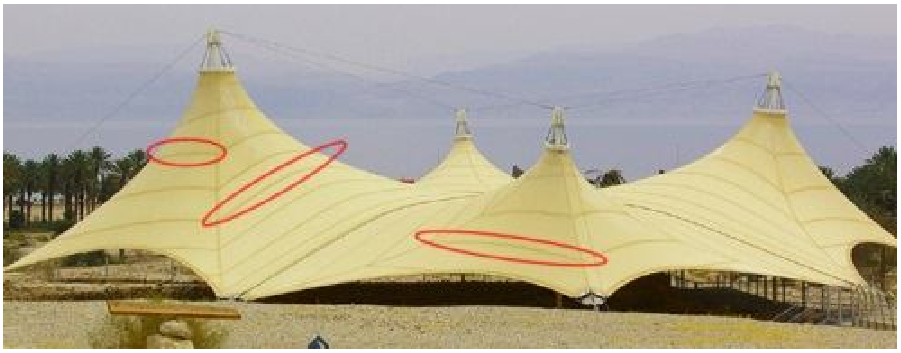


Figure 6.41, OasisGuggenheim–Bloch Architects, Sircovich–Labaton Structural Engineers

6.1.7. Details of the Structure

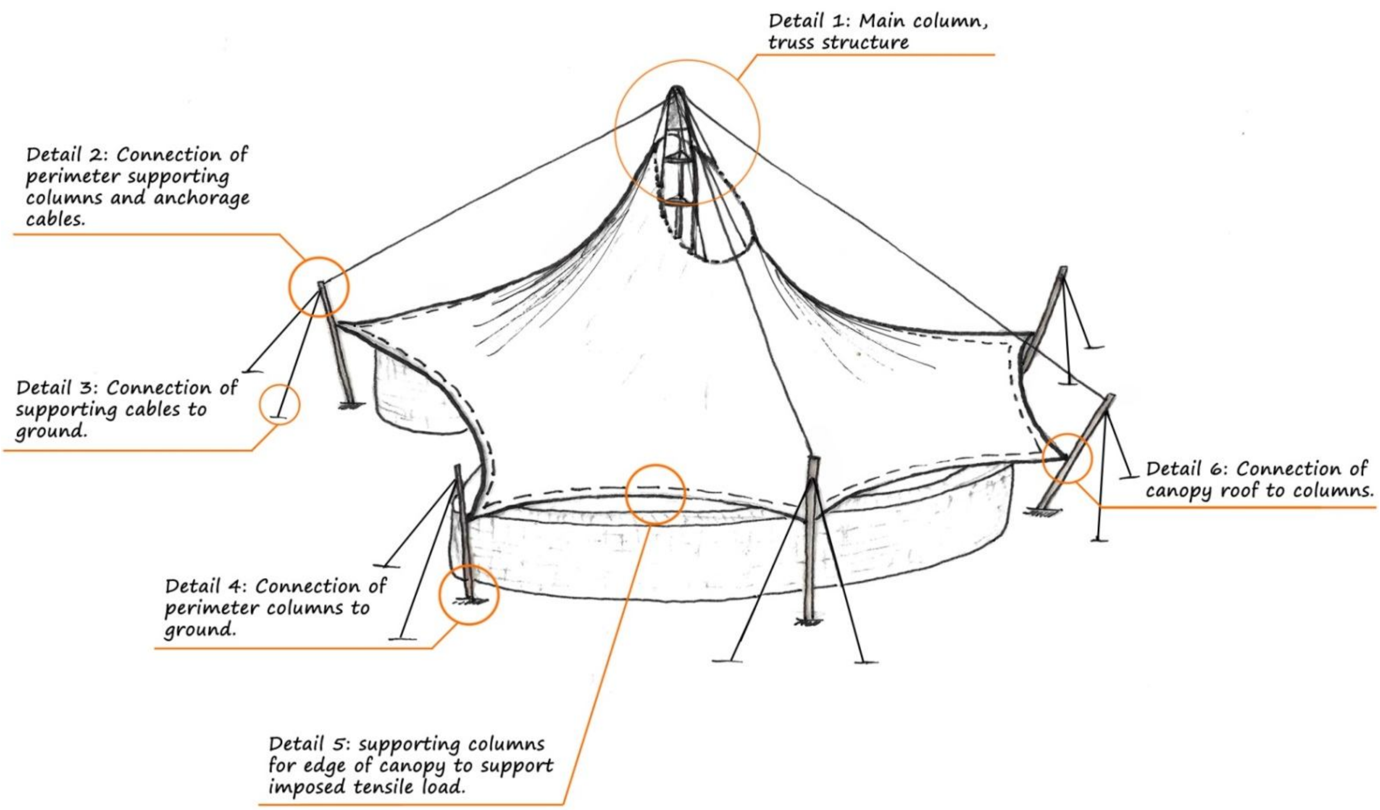
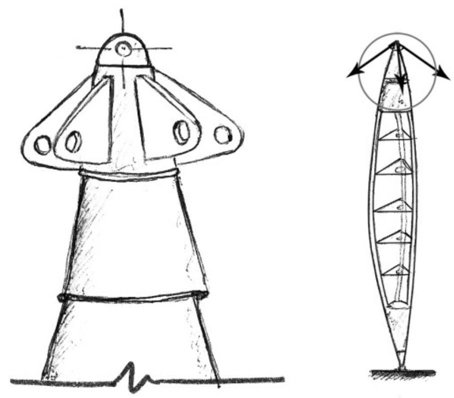


Figure 6.42, Canopy parts

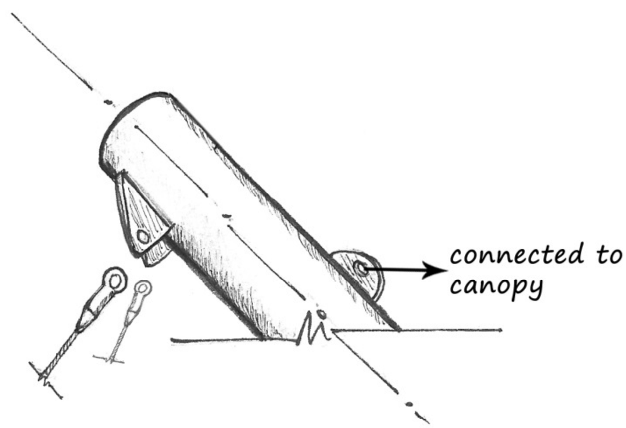
Detail 1:

The central column is a truss and will be anchored to several perimeter columns.



Detail 2:

Perimeter columns will be slightly inclined, from one side connected to canopy and from behind supported by two cables anchored to ground.



Detail 3:

Connection of supporting cables to the ground.

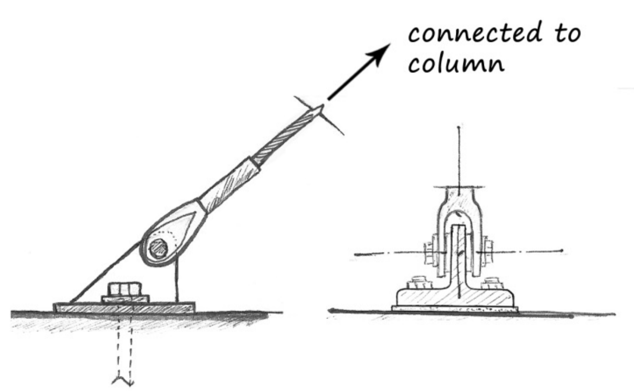
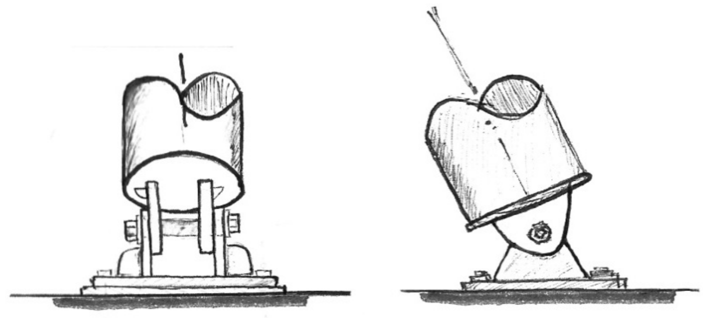


Figure 6.43, Schematic sketches of detailing, Detail 1,2,3

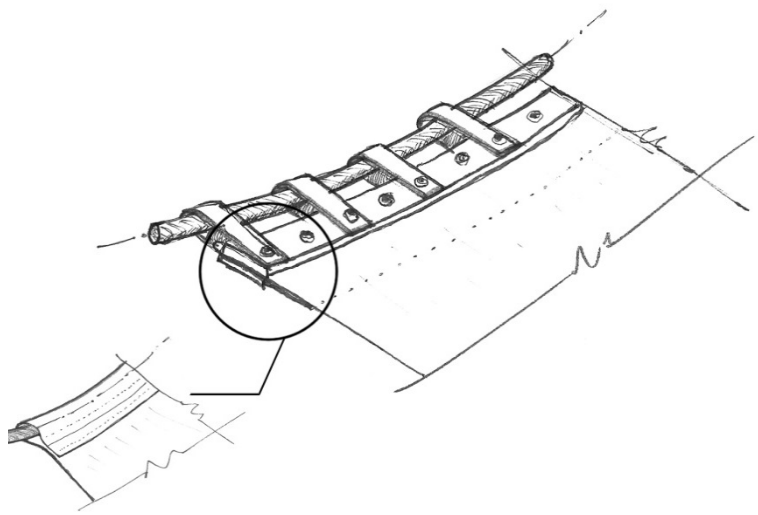
Detail 4:

Connection of supporting columns to ground. The connection is hinge. So the columns have 1 degree of freedom in one direction.



Detail 5:

The edge of the canopy fabric is supported by an additional cable, bearing the tensile lead and maintaining the curvature.



Detail 6:

The connection of canopy fabric to supporting columns

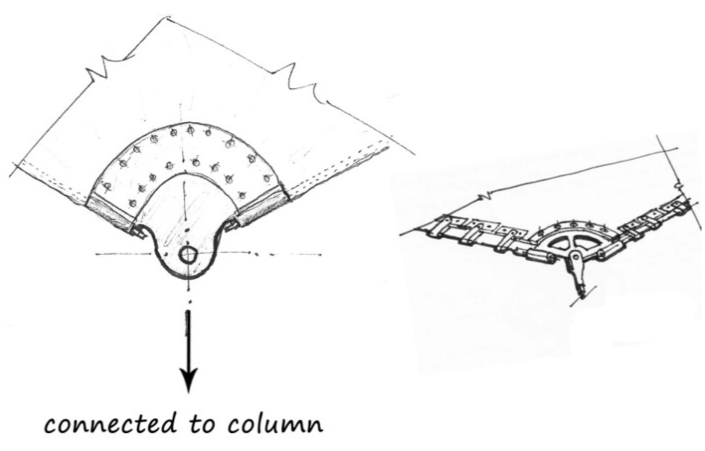


Figure 6.45, Schematic sketches of detailing, Detail 4,5,6

6.1.8. Construction of Gallery

6.1.8.1. Main Concept

The main concept behind design of art gallery inside the Castle is focused on:

- Minimum intervention to island and the castle
- Fast construction and simplicity of transportation
- Reusability of gallery for new or same function in another location
- Reversibility of construction method
- Light but durable structure
- Efficient building method with promising thermal efficiency
- Availability of construction method in the area while it has to be also economical
- Sustainability of materials and construction

Based on these considerations we proposed SIP construction method for gallery. The whole galley is constructed by six independent boxes which will be connected together. As described above all the structure can be dismantled again in future and each of these boxes can be installed separately with a new function. The diagram bellow schematically shows the construction method of both cases when we build the gallery inside Castle Pinckney and future reuse of the structure for a new function.

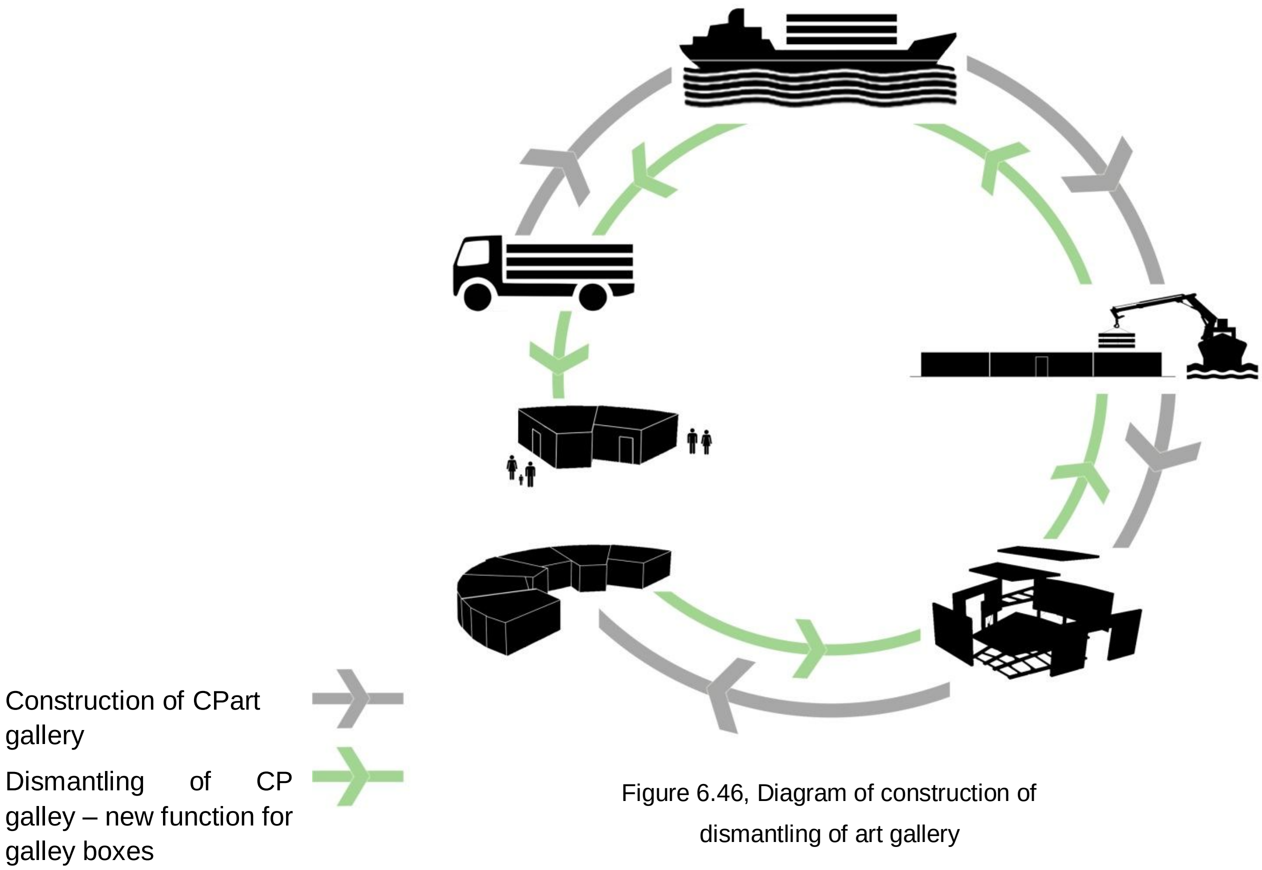


Figure 6.46, Diagram of construction of dismantling of art gallery

6.1.8.2. Construction Method

Structural insulated panels, SIP, are a composite building material. They consist of an insulating layer of rigid core sandwiched between two layers of structural board. The board can be metal, plywood, cement, magnesium oxide board or oriented strand board (OSB) which are more common and the core either expandedpolystyrene foam (EPS), extruded polystyrene foam (XPS), polyisocyanurate foam, polyurethane foam or composite honeycomb (HSC).

SIPs share the same structural properties as an I-beam or I-column. The rigid insulation core of the SIP acts as a web, while the sheathing fulfills the function of the flanges. SIPs combine several components of conventional building, such as studs and joists, insulation, vapor barrier and air barrier. They can be used for many different applications, such as exterior wall, roof, floor and foundation systems.

The use of SIPs brings many benefits and some drawbacks compared to a conventional framed building. The cost of SIPs is higher than the materials for a comparable framed building in the United States; however, this may not be true elsewhere. A well-built home using SIPs will have a tighter building envelope and the walls will have higher insulating properties, which leads to fewer drafts and a decrease in operating costs. Also, due to the standardized and all-in-one nature of SIPs, construction time can be less than for a frame home, as well as requiring fewer tradesmen. The panels can be used as floor, wall, and roof, with the use of the panels as floors being of particular benefit when used above an uninsulated space below. As a result, the total life-cycle cost of a SIP-constructed building will, in general, be lower than for a conventional framed one—by as much as 40%. Whether the total construction cost (materials and labor) is lower than for conventional framing appears to depend on the circumstances, including local labor conditions and the degree to which the building design is optimized for one or the other technology.

In summary, SIP structures benefit from:

- **Excellent Thermal Performance:** SIPs provide superior thermal performance, which will last the life span of the building. This is due to the solid core of insulation throughout the structure which ensures that the building is heated evenly, remains free from cold spots and will benefit from reduced heating costs.
- **Low U-value walls and roof:** SIP offers extremely high thermal performance, the Polyurethane (PUR) core of rigid insulation and OSB/3 achieves U-Values as low as 0.14 Watts per Meter Squared Kelvin (W/m2K) or better, making significant savings on your annual heating costs.
- **Integral Insulation:** The insulation is integral to the SIP system, and therefore eliminates the need and cost for cavity insulation.
- **Habitable Roof Space:** Build It Green SIP Building Systems do not require roof trusses, therefore providing an additional habitable room in the roof.

- **Extra Floor Space:** This system creates more internal floor space for the same external dimensions in comparison to masonry construction. This is because a SIP structure provides excellent strength and insulation in a smaller wall width.
- **Environmental Sustainability:** SIP is environmentally friendly for several reasons. Structural Insulated Panels are made from timber which is sourced from managed plantations. Timber is the only truly renewable building material. The insulation core is CFC/HCFC-free with zero Ozone Depletion Potential and has a Low Global Warming Potential (GWP).
- **Low Wastage:**Structural Insulated Panels are pre-engineered and pre-fabricated in factory which results in less defects and wastage.
- **Fast Construction Method:** By using SIP Panels, on-site construction time can typically be reduced by up to three times.
- **Design Flexibility:**Structural Insulated Panels can be designed to accommodate a wide variety of building applications.
- **Air-Tightness:** Poor air-tightness is a major cause of heat loss. A SIP structure provides a controllable indoor environment due to the superior air tightness of the system. This is enhanced with the use of a Mechanical Ventilation with Heat Recovery (MVHR) system or similar.
- **Limited Cold Bridging:** Panels are joined together with an insulated SIP spline providing a continuous polyurethane (PUR) core through the walls and roof of the building. This greatly improves the thermal efficiency of the building compared to timber frame studs and cavity insulation which is prone to slumping and mortar drops during the construction process.
- **Solid Panels Provide a Rigid Surface For Fixings:** In most cases, no additional timber 'noggins' are required to facilitate the hanging of radiators and kitchen units as is required with timber frame construction.
- **Excellent Resale Potential:**They are attractive to future buyers and occupiers, due to the inexpensive running costs of a SIP structure and the many other benefits a SIP home provides.

As described in the *diagram6.46*, the construction of each box will be simply done on site. All the panels are quite light and easy to mantle. The foundation of each box is “Screw Foundation” which is very easy to install and dismantle in future. The particular specification of this type of foundation is its minimum foot print on the ground. The *Figure 6.47&48*show the construction of each box for the gallery. The main panels of the floor are sited on a net of primary and secondary wooden beams which are connected to the ground through screw foundations.

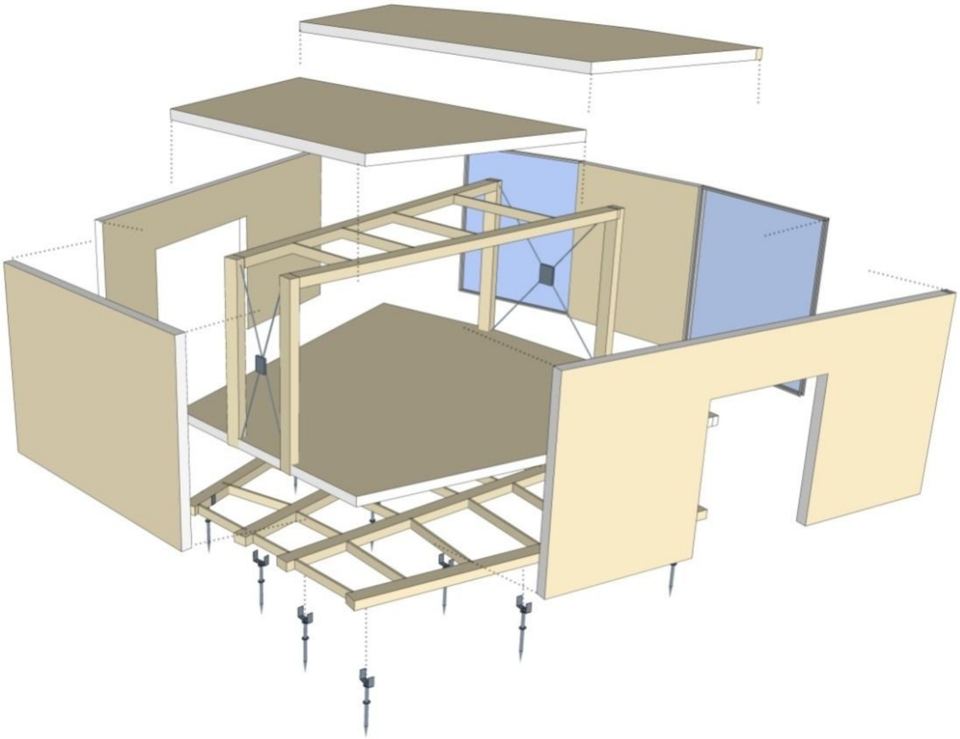
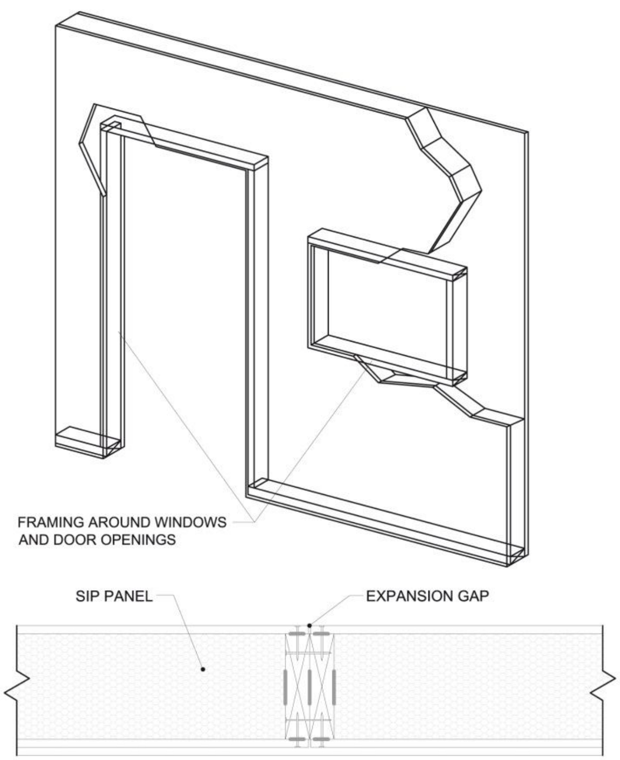
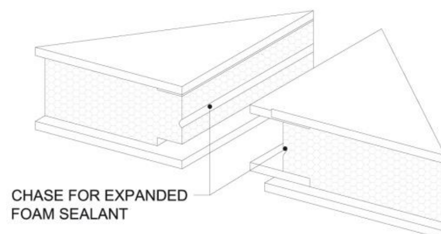


Figure 6.47, shows the construction of each box for the gallery.
Front and back bracing increase structure rigidity.





CASTLE PINCKNEY - SIP DRY WALL SPECIFICATION:	
LAYER:	**THERMAL CONDUCTIVITY:**
OSB PANEL (15 mm)	0.13 (Wm-1K-1)
INSULATION CORE FOAM: EXPANDED POLYSTYRENE (EPS) EXTRUDED POLYSTYRENE (XPS) POLYURETHANE FOAM (PUR)	 0.03 (Wm-1K-1) 0.035 - 0.045 (Wm-1K-1) 0.025 (Wm-1K-1)
OSB PANEL (15mm)	0.13 (Wm-1K-1)
U VALUE: SIP PANEL THICKNESS (PUR): 132 mm U= 0.23 (W/m2K) 150 mm U= 0.19 (W/m2K) 195 mm U= 0.14 (W/m2K)	
NOTE: For proposal panels for exterior walls are 195 mm and for the roof is 150 mm.	

Figure 6.48, SIP panel and door and window frame – connections
of SIP panels to each other – Panel's specification

Chapter 7

Technology

Chapter 7

Technological design

This Section deals with technologies applied to our project. Beginning with a review on weather information of Charleston City to passive strategies we have used to improve the concept to design. Initial simulations and analysis have guided our technological design in an extensive way to add or subtract elements from architectural design with the sole purpose of tackling these issues early on in the design.

7.1. Weather Information

Charleston has a humid subtropical climate, with mild winters, hot, humid summers, and significant rainfall all year long. Summer is the wettest season; almost half of the annual rainfall occurs during the summer months in the form of thundershowers. Fall remains relatively warm through November. Winter is short and mild, and is characterized by occasional rain. Snow flurries seldom occur, although in 2010, 3.4 inches (8.6 cm) fell on the evening of February 12, the heaviest in 20 years. The highest temperature recorded (inside city limits at the Customs House on E. Bay St.) was 104 °F (40 °C), on June 2, 1985, and the lowest temperature recorded was10 °F (−12 °C) on January 21, 1985. Hurricanes are a major threat to the area during the summer and early fall, with several severe hurricanes hitting the area – most notably Hurricane Hugo on September 21, 1989. Here in the table below we can see a summary of climate condition taken from Climate Consultant V5.4:

LOCATION: **CHARLESTON, SC, USA**
Latitude/Longitude: 32.9° North, 80.03° West, **Time Zone from Greenwich** -5
Data Source: TMY2-13880 722080 WMO Station Number, **Elevation** 12 m

ASHRAE Standard 55-2004 using PMV (Predicted Mean Vote) Model (select Help for definitions)

1. COMFORT: (using ASHRAE 55 PMV Model)	
1.0	Winter Clothing Indoors (1.0 Clo=long pants,sweater)
0.5	Summer Clothing Indoors (.5 Clo=shorts,light top)
1.1	Activity Level Daytime (1.1 Met=sitting,reading)
90.0	Predicted Percent of People Satisfied (100 - PPD)
20.3	Comfort Lowest Winter Temp calculated by PMV model(ET* C)
24.3	Comfort Highest Winter Temp calculated by PMV model(ET* C)
26.7	Comfort Highest Summer Temp calculated by PMV model(ET* C)
84.6	Maximum Humidity calculated by PMV model (%)
2. SUN SHADING ZONE: (Defaults to Comfort Low)	
20.3	Min. Dry Bulb Temperature when Need for Shading Begins (°C)
315.5	Min. Global Horiz. Radiation when Need for Shading Begins (Wh/sq.m)
3. HIGH THERMAL MASS ZONE:	
8.3	Max. Dry Bulb Temperature Difference above Comfort High (°C)
2.8	Min. Nighttime Temperature Difference below Comfort High (°C)
4. HIGH THERMAL MASS WITH NIGHT FLUSHING ZONE:	
16.7	Max. Dry Bulb Temperature Difference above Comfort High (°C)
2.8	Min. Nighttime Temperature Difference below Comfort High (°C)
5. DIRECT EVAPORATIVE COOLING ZONE: (Defined by Comfort Zone)	
20.0	Max. Wet Bulb set by Max. Comfort Zone Wet Bulb (°C)
6.6	Min. Wet Bulb set by Min. Comfort Zone Wet Bulb (°C)
6. TWO-STAGE EVAPORATIVE COOLING ZONE:	
50.0	% Efficiency of Indirect Stage
7. NATURAL VENTILATION COOLING ZONE:	
2.0	Terrain Category to modify Wind Speed (2=suburban)
0.2	Min. Indoor Velocity to Effect Indoor Comfort (m/s)
1.5	Max. Comfortable Velocity (per ASHRAE Std. 55) (m/s)
8. FAN-FORCED VENTILATION COOLING ZONE:	
0.8	Max. Mechanical Ventilation Velocity (m/s)
3.0	Max. Perceived Temperature Reduction (°C)
	(Min Vel, Max RH, Max WB match Natural Ventilation)
9. INTERNAL HEAT GAIN ZONE:	
12.8	Balance Point Temperature Above Which Building Runs Free (°C)
10. PASSIVE SOLAR DIRECT GAIN LOW MASS ZONE:	
157.7	Min. South Window Radiation for 5.56°C Temperature Rise (Wh/sq.m)
3.0	Thermal Time Lag for Low Mass Buildings (hours)
11. PASSIVE SOLAR DIRECT GAIN HIGH MASS ZONE:	
157.7	Min. South Window Radiation for 5.56°C Temperature Rise (Wh/sq.m)
12.0	Thermal Time Lag for High Mass Buildings (hours)
12. WIND PROTECTION ZONE:	
8.5	Min.Velocity above which Wind Protection is Desirable (m/s)
11.1	Min. Dry Bulb Temperature Difference Below Comfort Low (°C)
13. HUMIDIFICATION ZONE: (directly below Comfort Zone)	
14. DEHUMIDIFICATION ZONE: (directly above Comfort Zone)	

Figure 7.1, A general weather condition of Charleston (SC), provided by Climate Consultant V. 5.4

7.2. General Strategies

In building sector the highest energy saving potentials can be realized by energy efficient building design. The energy efficiency of buildings is significantly influenced by architectural design aspects, such as orientation, shape of the building structure, location of windows and opening, etc.

In general there are following strategies for the design of energy efficient buildings:

- Minimization of losses
- Maximization of solar gains in heating case
- Minimization of solar gains in cooling case
- Minimization of electricity demand for artificial lighting

Looking back in history we can see that building design, besides other factors (social aspects, availability of building materials, etc.) always was a result of the climatic conditions on the building site. Today the mainstream of modern architecture is neglecting these climatic conditions, compensating inefficient building design with enormous efforts concerning the energy supply for heating, cooling and lighting. To design energy efficient buildings (Low-Tec Buildings) architectural concepts have to integrate this old knowledge and develop new innovative design solutions based on climatic aspects.

Theaim behind our design for restaurant and art gallery is to obtain best results through most suitable strategies to be energy efficient while providing comfort for users. This is obtained by an appropriate schematic design plus optimization by computerized calculations and analysis with the help of Ecotect software.

7.3. Castle Pinckney

The Castle has a special location which requires special attention. ShutesFolly Island is almost 1.7 Km far from main land and so there are some limitations for installations and providing energy and facilities for fort Pinckney. The general concept is to make the island self-supported and independent from Charleston city as much as possible.

Some of these strategies are followings:

- On-site production of electricity for activities inside and outside the gallery from waves, wind, sun light and high tide.
- Collection and circulation of rain water in the center of court yard plus around the boundary of canopy roof.
- Selection of Sip-Panel system for gallery which is energy efficient with a very low U value.
- Consideration of openings for gallery boxes which lets fresh air to come inside. So the air conditioning for cooling and heating system will take benefit from fresh air.

Let’s have a look at a schematic section of the Castle which illustrates some of these mentioned systems and facilities:

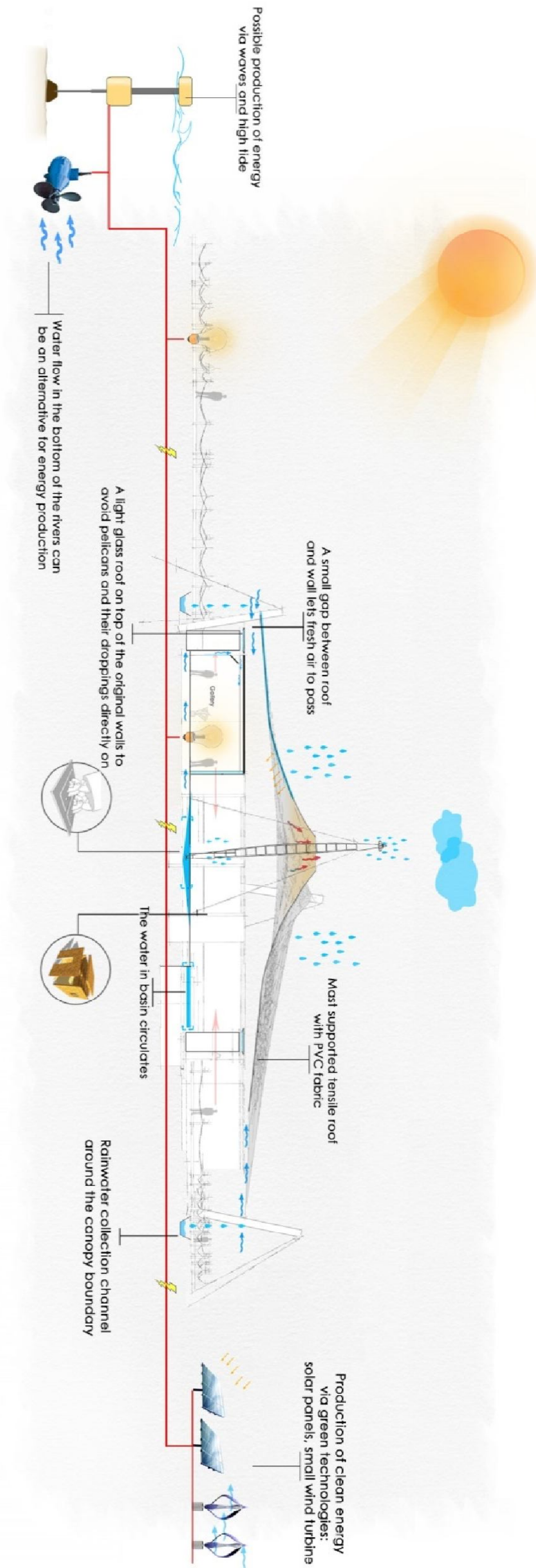


Figure 7.2, Schematic design section of Castle – General technical strategies are mentioned

Getting closer to the design of art gallery inside the castle, we started to model the whole building in Ecotect to observe the effect of proposed tensile roof with its hole and the efficiency of SIP panels proposed for gallery itself through the calculation of cooling and heating demand.

7.3.1. Light and Shadow Analysis

The initial phase of analysis was studying the shadow and light inside the court yard where we cloud understand the influence of the hole for sunlight and transparency of canopy. *Figure 7.3*illustrates the whole model inEcotect and the position of sun:

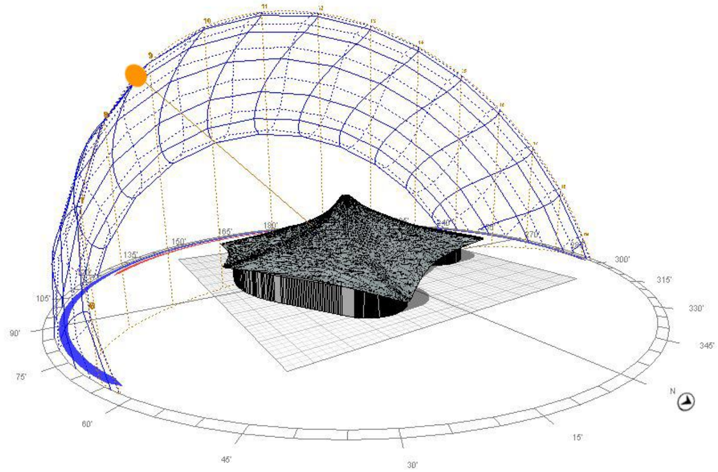


Figure 7.3, Daily & Annual sun path – Castle position

Our next step was to understand the effect of proposed hole on the roof and observe thelightening inside the courtyard. The approach was optimization of shape and size of the hole in order to achieve adequate sun lightfor the area next to the entrance and cafeteria. *Figure 7.4*from left to right shows our proposals for the hole in 3 steps. The right one is the final shape and all Ecotect simulations are done based on this form.

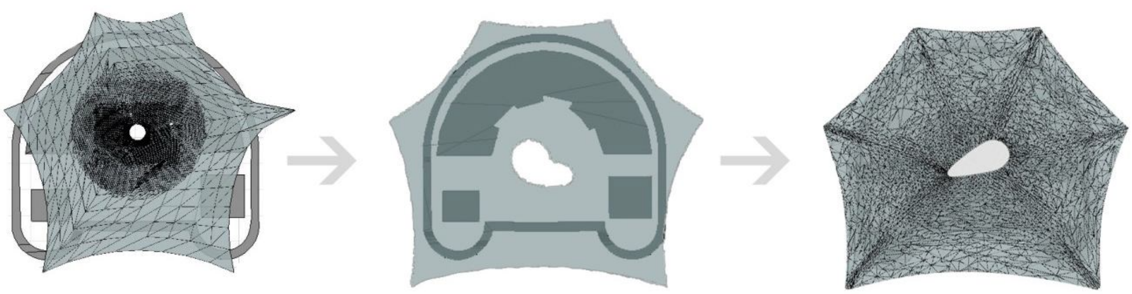


Figure 7.4, Design process from left (primary design) to right (final proposal)

This form of opening in tensile roof helps us to reach desirable sunlight inside the castle while its form can be simply done by the help of central column and cables which hold boundary of the hole. To understand better shadows of the roof and light which comes inside from the hole, we have shown in the *Figure 7.5* change of shadow during the day, 3 time of a day, 9 Am, midday and 4 Pm for 4 important period of the year: Summer & Winter Solstice , Spring & Autumn Equinox. Therefore 21st of June, March, December and September.

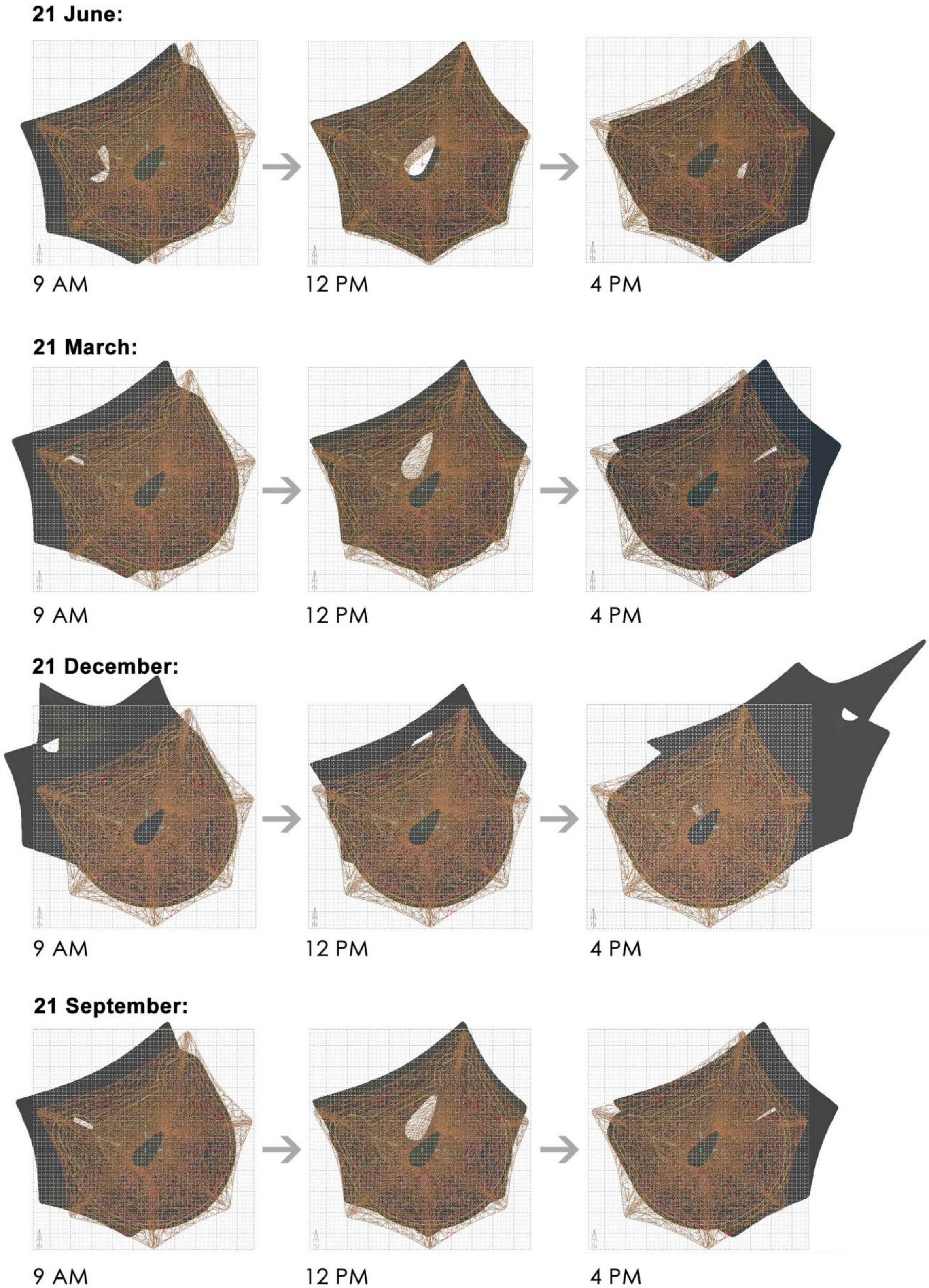
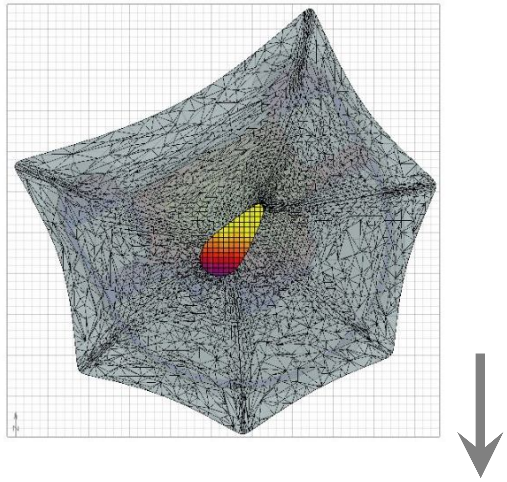
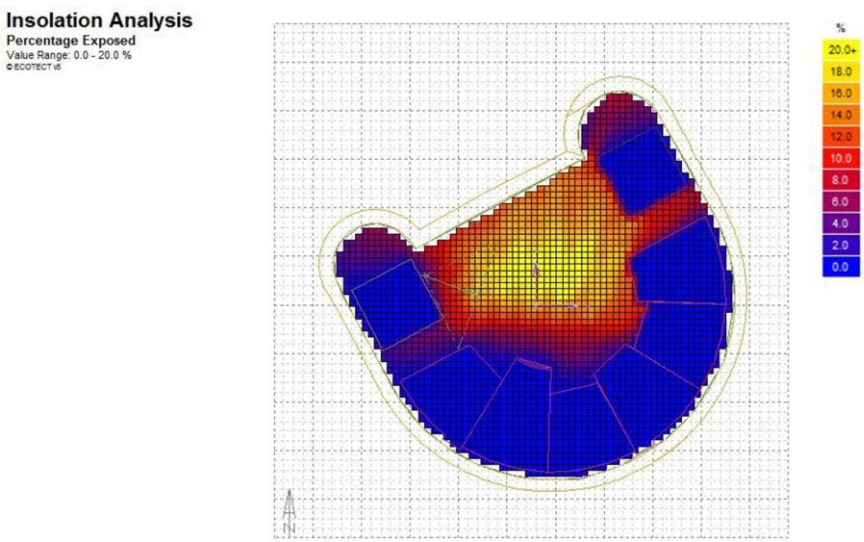
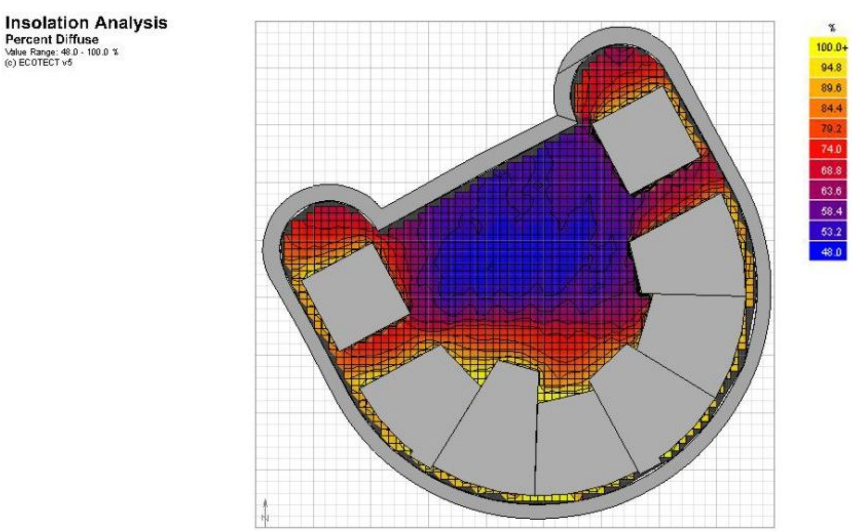


Figure 7.5, Roof shadow variation during a day, for specific dates of the year.

In next step we used insolation analysis of Ecotect to achieve percentage of exposed, diffuse, direct and total sunlight hours. The results are shown below:







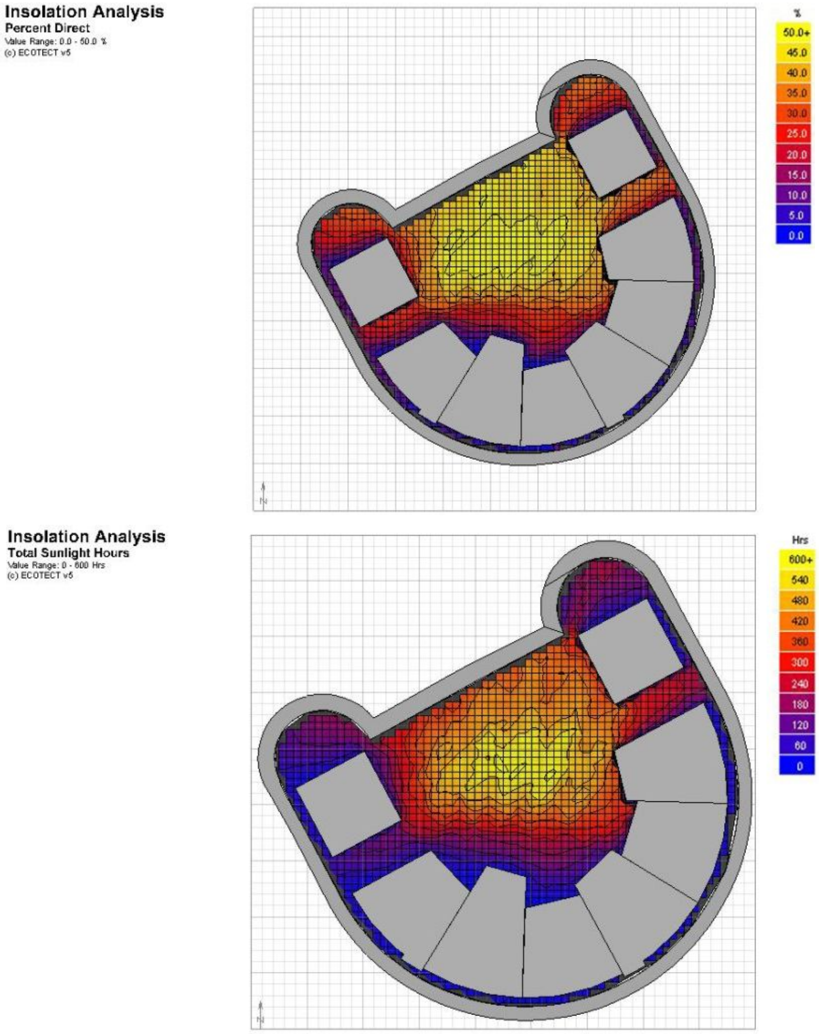


Figure 7.6, Insolation Analysis result. Percentage exposed, Percent diffuse, Percent direct, Total sunlight hours

The result of analysis clearly reveal the effect of considered hole and all the area beneath which take advantage of direct or diffuse solar light, coming through the hole. As described before the aim was to have more light in up right side of the castle where there are entrance and sitting area for cafeteria. It is obvious that those areas are brighter with more hours of sunlight during the year, in moths that sun is relatively high.

7.3.2. Thermal Analysis

The next phase of analysis is about the heating and cooling demand of gallery mass for all months of the year. The galley construction is not only fast and easy to build but also energy efficient. Sip-Panels with high u vale (0.14 W/m^2K for 195 mm thickness) offer a significant high efficient building. We expect the Heating-Cooling loads to be relatively low as the panels and windows are both efficient. We inserted the U= 0.14 (W/m^2K) for all the panels, roof, walls and floor and 2.26 (W/m^2K) for windows which are considered as double glazed with timber frame.

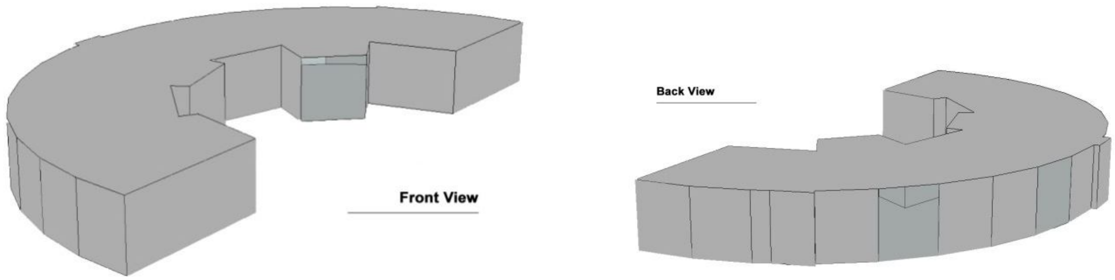
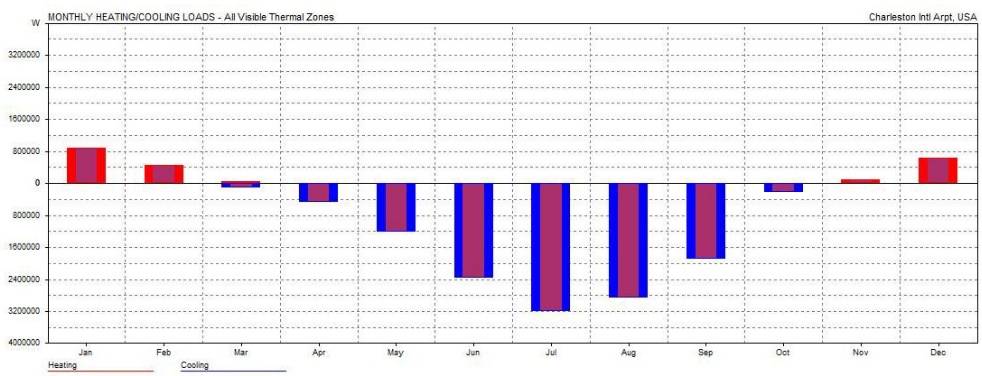


Figure 7.7, Gallery box modeled in Ecotect, Front and back view

For the Zone Management setting we considered 50 people inside the gallery, as an average of visitors with 80 W biological heat output of each person. A value of 0.5 has been inserted for Air Change Rate. Active system for providing heating and cooling has been considered as Mixed-Mode system as within our design scheme we have considered openings for galley for fresh air and also we propose systems which use a combination of both Natural ventilation plus air conditioning. Thermostat range is between 18 C°-24 C° because psychometric diagram defines this range as comfort. As a schedulefor air-conditioning operation, we have considered between 9 Am until 8 Pm. The results are shown below:



Monthly Heating & Cooling load		
All visible Thermal Zones		
Comfort: Zonal Bands		
Max heating: 10801 W at 9:00 28th January		
Max cooling: 16802 W at 14:00 13th July		
Monthly	**Heating (Wh)**	**Cooling (Wh)**
Jan	885113	0
Feb	457437	0
Mar	34781	119056
Apr	0	464262
May	0	1218876
Jun	0	2356353
Jul	0	3196896
Aug	0	2866280
Sep	0	1901254
Oct	477	221216
Nov	93354	7202
Dec	622842	0
Total	2094005	12351395
Per M2	5578	32899
Floor Area: 375.433 m2		

Figure 7.8, Gallery thermal analysis results, Monthly heating & cooling demand

Total Heating and Cooling loads are consequently 5.578 KWh/m^2 and 32.89 KWh/m^2. This result clearly shows that gallery consumes more energy during summer and hot days to cool down the air inside, starting from March up to November and specifically in July which has maximum value. Charleston city in general has a hot and humid climate most of the year so the result is quite realistic. We assume the considered windows for galley boxes which can be open during the day will help the inside air to be fresher and cooler.

7.4. Restaurant

To reach a good design for restaurant we took into consideration several daylightanalyses to achieve the best result.A good design always considers climate situation of design area and all related issues such as, the orientation of building itself, requirements of daylighting for interior space, position of sun according to building, proper shading system for glazed facades in order to control direct sunlight coming inside while respecting visual connection between people and landscape outside, etc. *Figure 7.9*shows the orientation of restaurant.

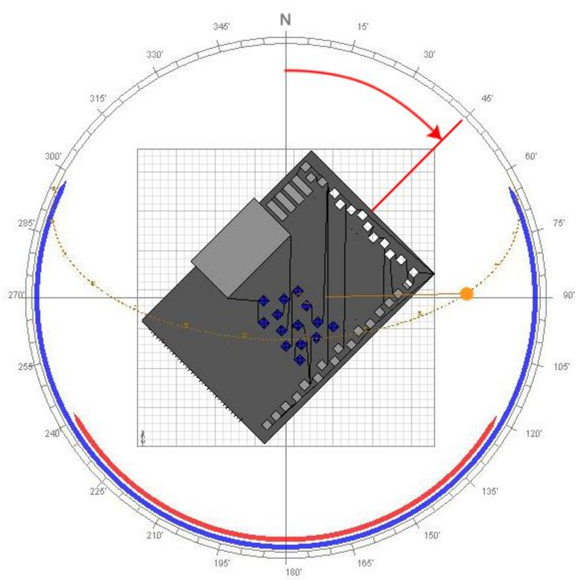


Figure 7.9, Orientation of restaurant building

The orientation of building has an important reason. It has been rotated for about 45° in order to provide a convenient directvisual connection for people inside towards Castle Pinckney and all the landscape. Restaurant is not surrounded by any other adjacent building and therefore sun rays directly hit the building. As described before Charleston city has a relevant hot and humid climate most of the year. Using this building as a restaurant makes some limitations for design and requires special attention to interior lighting levels. Primary daylight analysis via Velux software over the plan of building, shown in *Figure 7.10*, it reveals that our design requires deeper analysis of lighting and shading.

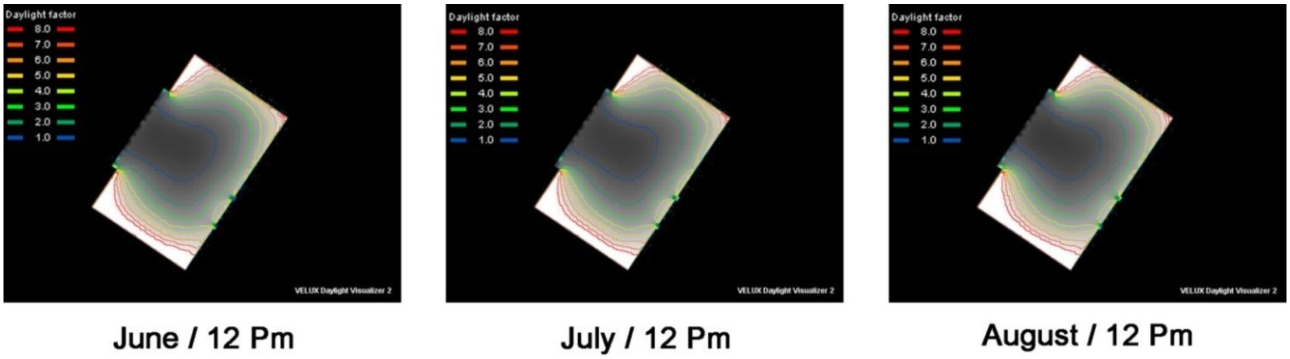


Figure 7.10, Velux result for 21st of June, July and August

The central area of restaurant is a bit darker as it has the maximum distance with glazing facades. South-west part gains more sun light. This means that during summer and hot seasons this area close to glazing is moderately hot with direct sun light on tables or even high amount of glare. In order to solve these problems, we have considered a series of light analysis inside the restaurant based on shading and lighting basics to optimize the daylight factor and design the best shading.

The use of sun control and shading devices is an important aspect of many energy-efficient building design strategies. In particular, buildings that employ passive solar heating or daylightingoften depend on well-designed sun control and shading devices. The design of effective shading devices will depend on the solar orientation of a particular building facade. For example, simple fixed overhangs are very effective at shading south-facing windows in the summer when sun angles are high. However, the same horizontal device is ineffective at blocking low afternoon sun from entering west-facing windows during peak heat gain periods in the summer.

Figure 7.11 shown below illustrates roughly the best shading type for each side. To avoid over heating during the summer when the sun position is high in the sky, the shading should be horizontal while for the east and west side the vertical shading louvers are recommended. These louvers will diffuse the sunlight when the sun position is low, for instance at the time of sunrise and sunset. In some cases a proper combination of different types can be even more effective. For new modern buildings an automatic system of vertical louvers are installed which are movable according to the angle of sun rays. This is also the recommended system for our restaurant.

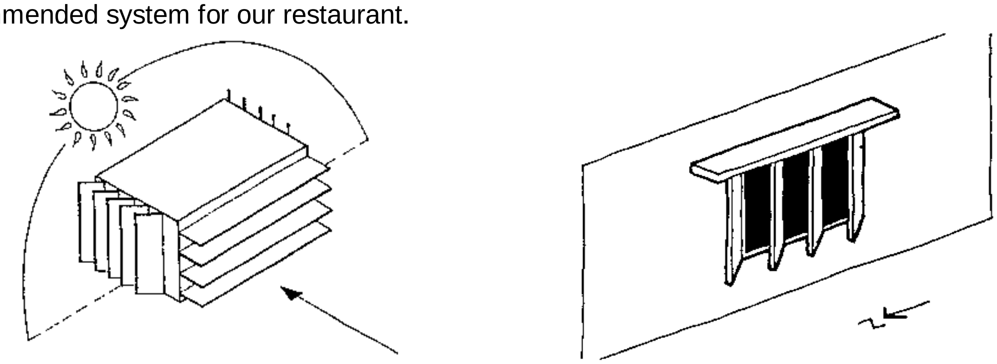


Figure 7.11, Orientation of shading according to cardinal direction

Exterior shading devices are particularly effective in conjunction with clear glass facades. However, high-performance glazing are now available that have very low shading coefficients (SC). When specified, these new glass products reduce the need for exterior shading devices.Thus, solar control and shading can be provided by a wide range of building components including:

- Exterior elements such as overhangs or vertical fins;
- Horizontal reflecting surfaces called light shelves;
- Low shading coefficient (SC) glass; and,
- Interior glare control devices such as Venetian blinds or adjustable louvers
- Landscape features such as mature trees or hedge rows, where possible;

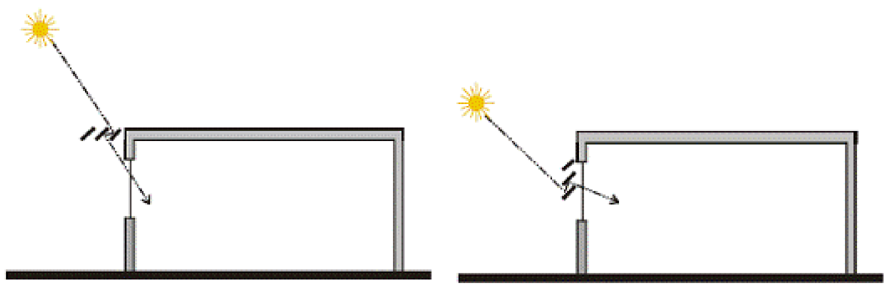


Figure 7.12, Vertical and Horizontal Louvers to Re-direct Sunlight

Generally exterior shading has priority to interior type because the exterior shading will block sun light outside the building before sun rays pass through the glazing while interior shading diffuse sunlight while it is already inside the building. As shown in the *Figure 7.13,* internal shading or blinds cause major problems during summer and thus increases cooling load.

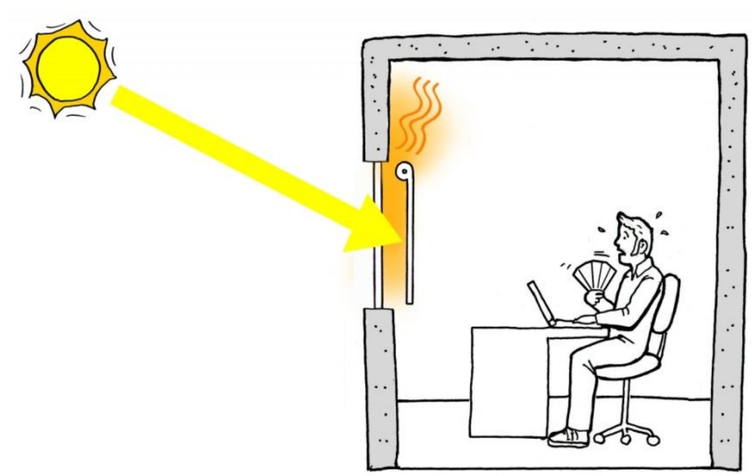


Figure 7.13, Negative effect of internal shading

To properly design shading devices, it is necessary to understand the position of the sun in the sky during the cooling season. The position of the sun is expressed in terms of altitude and azimuth angles. In *Figure 7.14*we can see the orientation of building and sun positions during a year.

Shading devices can have a dramatic impact on building appearance. This impact can be for the better or for the worse. The earlier in the design process that shading devices are considered they more likely they are to be attractive and well-integrated in the overall architecture of a project.

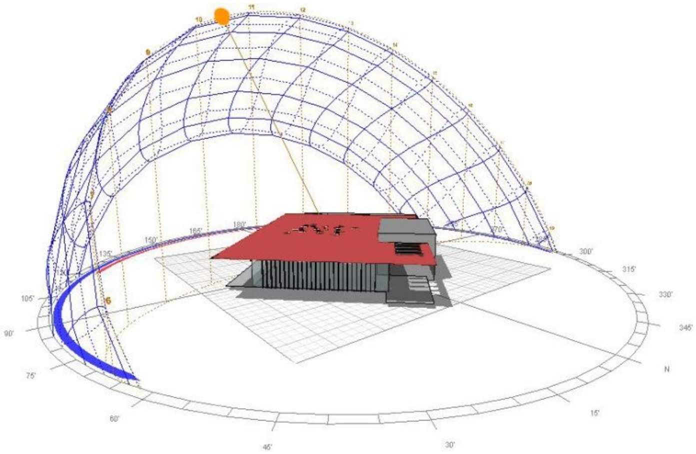


Figure 7.14: Daily & Annual sun path – Restaurant position

7.4.1. Shading Scenarios, Daylight Analysis

In order to design and understand the proper shading for 3 glazed sides of the building, we have introduced 4 different scenarios. We considered a combination of horizontal overhangs and vertical louvers for south-west side. On south-east side of the building there is a big extension of roof which creates proper shading for that façade but we added horizontal and movable louvers for the time that sun position is relatively low and sharp angle sun rays are coming inside. The north-east side of the building which is attached to the ramp has also an extension of roof to cover the ramp but we also propose vertical louvers for glazing façade.

So we start with the building without any shading and for each scenario we add one of those mentioned shadings to compare results. In last step we do a daylight analysis for the building with all those shadings.

Case 1:

Daylight analysis, Daylight Factor (%) and Daylight Levels (Lux) – Building without any shading and over hangs:

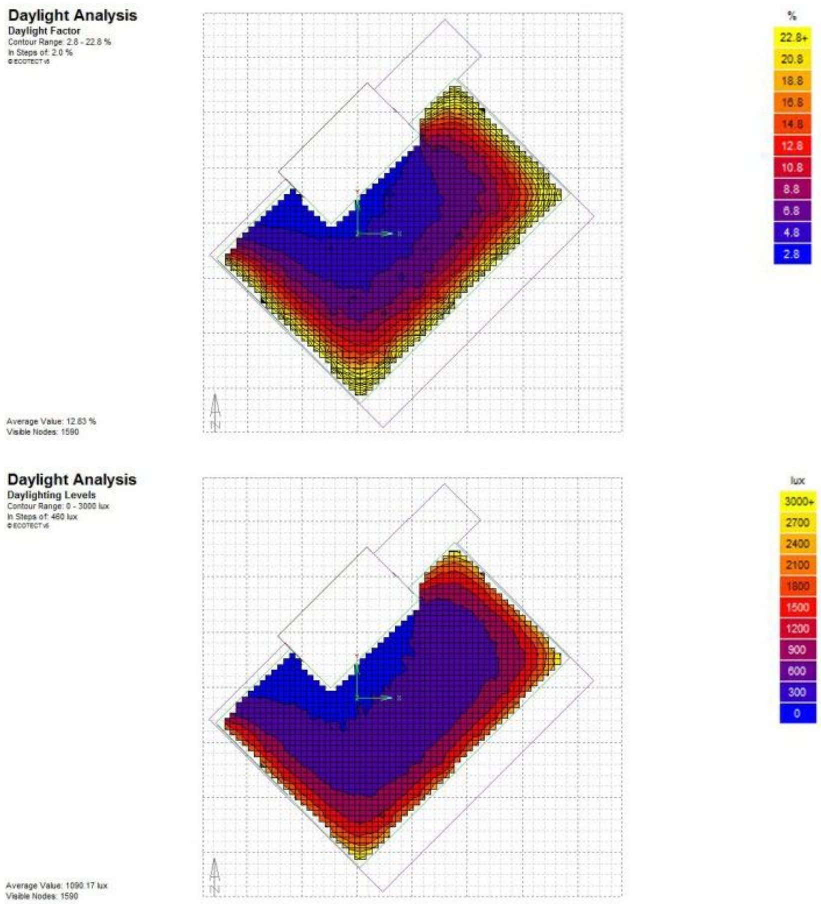


Figure 7.15, Daylight analysis for Case1, Daylight Factor
and Daylighting levels

The result clearly shows all the area close to glazing side of building has nearly 20% of daylight Factor which is very high and subsequently high amount pf daylight level which may cause glare and discomfort for people inside. The average daylight factor is 12.83% and we aim to reduce it to nearly 8%.

Case 2:

Daylight analysis, Daylight Factor (%) and Daylight Levels (Lux) – Extension of roof for South-East and North-East side:

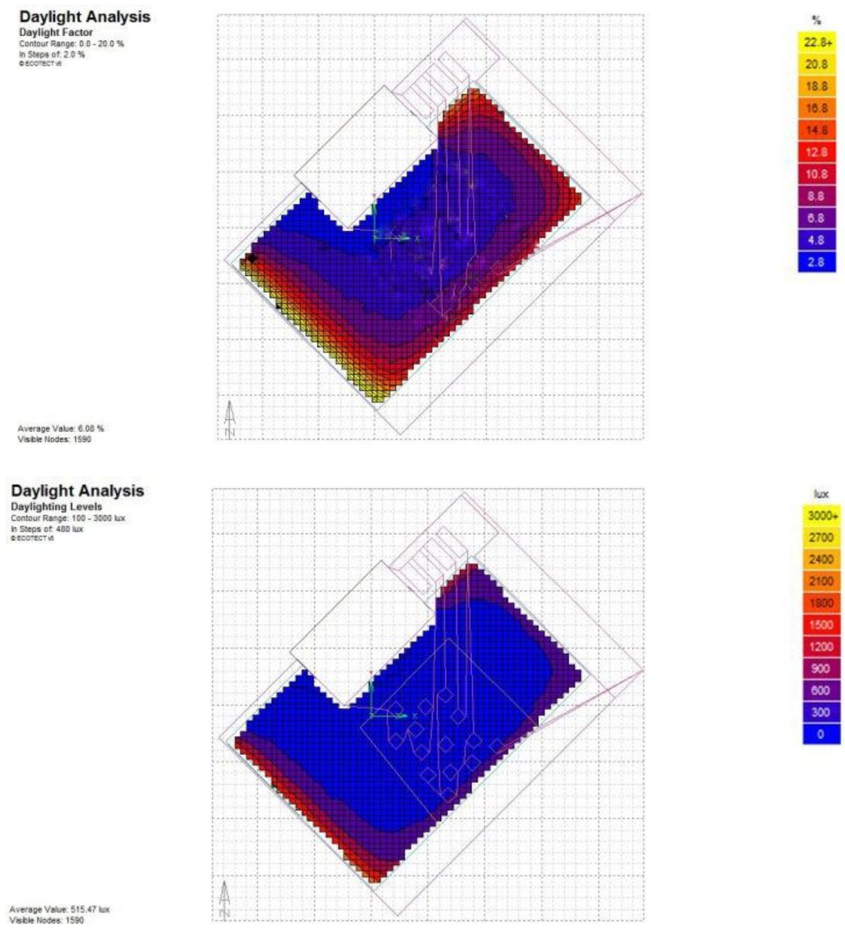


Figure 7.16, Daylight analysis for Case2, Daylight Factor
and Daylighting levels

Based on the result the average daylight factor arrived to 6%, so the shading by the means of roof extension is beneficial but daylight level is much lower than before in restaurant area. In order to increase day light in the central part we have considered skylights on the roof. In the following case we add the skylight to compare the results.

Case3:

Daylight analysis, Daylight Factor (%) and Daylight Levels (Lux) – Extension of roof for South-East and North-East side plus addition of skylight:

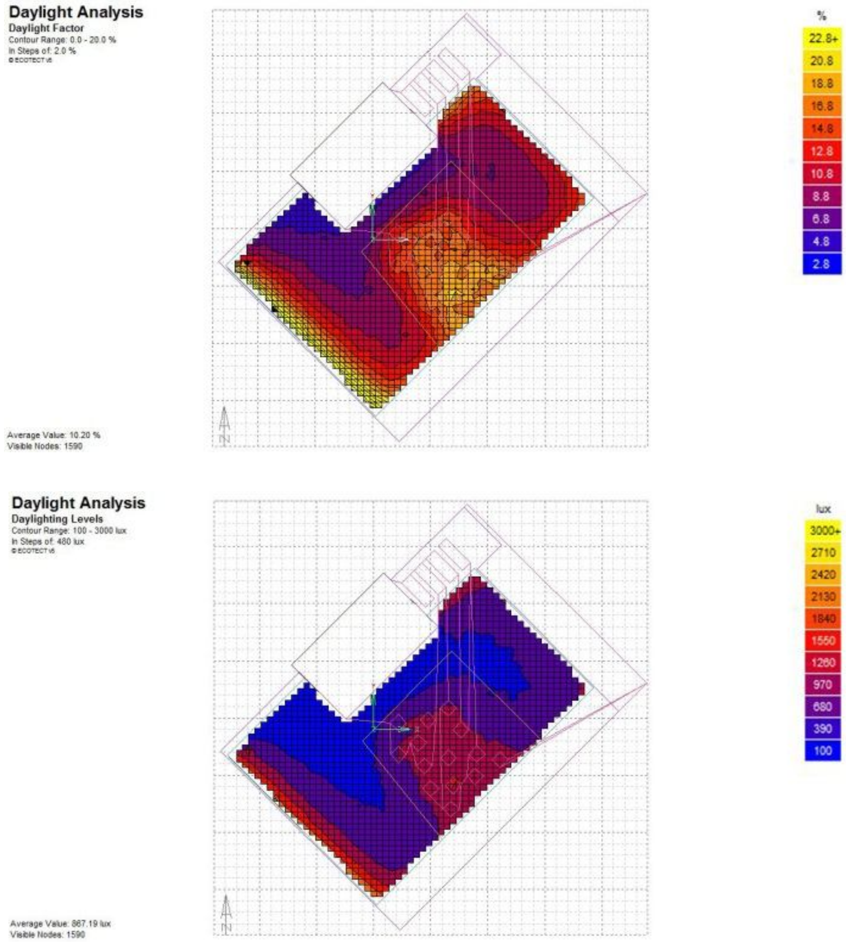


Figure 7.17, Daylight analysis for Case3, Daylight Factor and Daylighting levels

As expected added skylight to central part of the roof had a positive effect and increased both daylight factor and lighting levels. In the last case we add shadings to glazing system and we run again the analysis.

Case 4:

Daylight analysis, Daylight Factor (%) and Daylight Levels (Lux) – Extension of roof for South-East and North-East side, skylights and addition of shading:

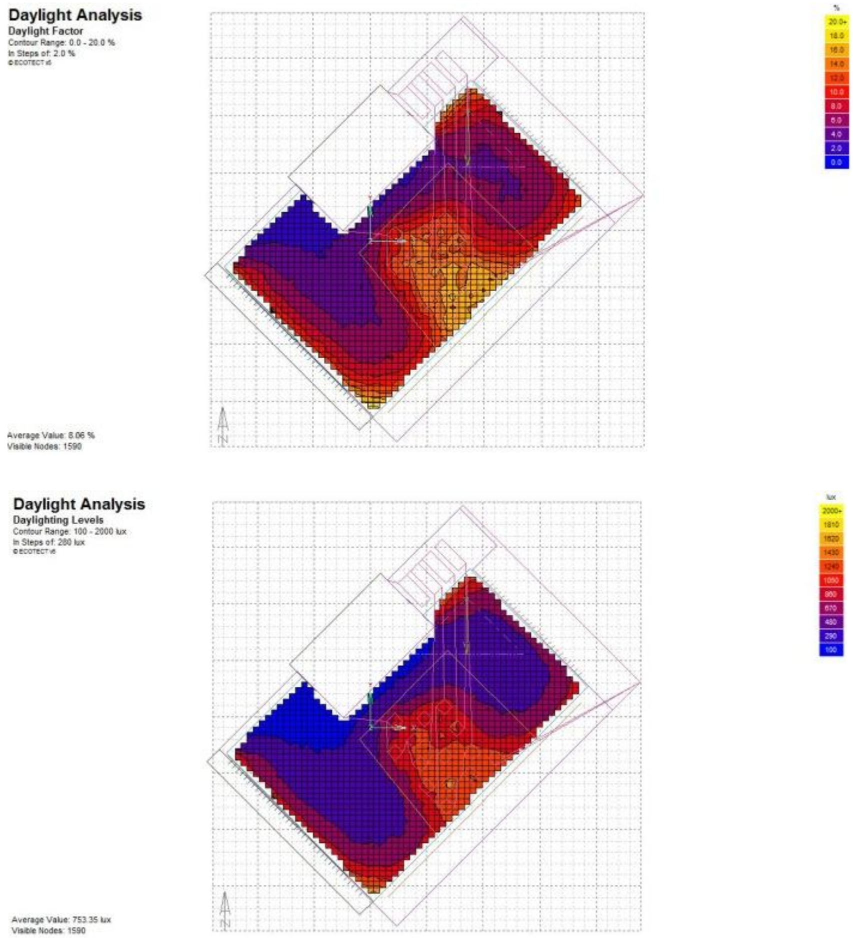


Figure 7.18, Daylight analysis for Case4, Daylight Factor and Daylighting levels

The final calculation had the best result. The average daylight factor is almost 8% and very close to our target. Lighting level is also good and nearly 400 Lux for the major area with dining tables. We believe these values are still modifiable by adjusting mechanical louvers. Therefore based on weather condition and time of the day we can adjust the incoming sun light. For the south-west façade the combination of vertical and horizontal shading worked more effective. The visual connection of people inside the restaurant with the castle and a unique panoramic landscape view is strongly whiting our design scheme, so the vertical louvers will be installed with a proper distance with each other, not to block this visibility.

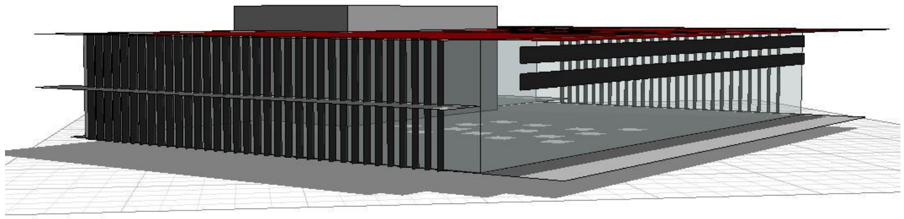


Figure 7.19, Final model in Ecotect

The horizontal shadings are also made of several narrow louvers so they let a diffuse light and rain water passing through. Two schematic sections of restaurant shown below show the functionality of these shadings during summer when the sun is high in the sky and winter when its position is lower.

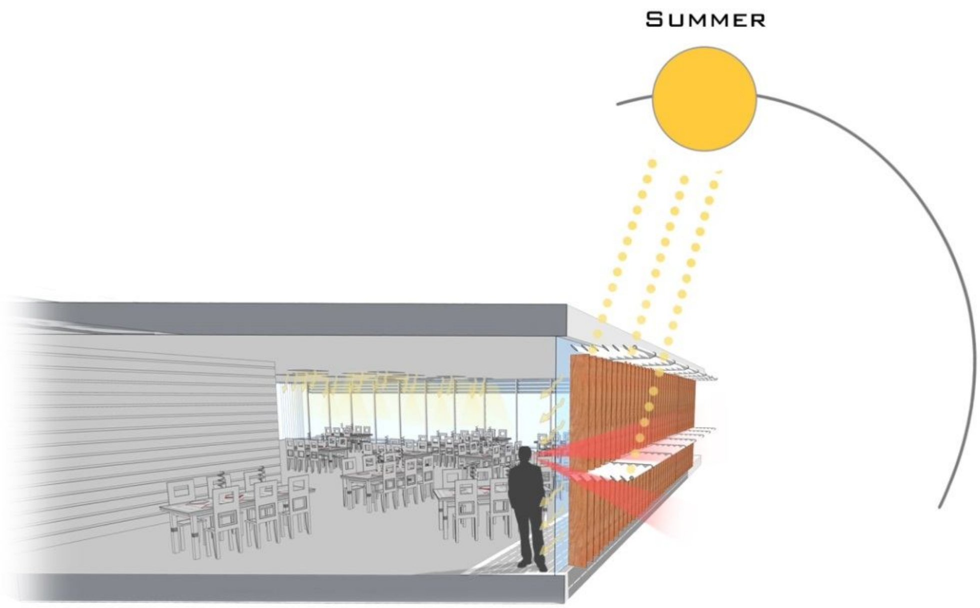


Figure 7.20, A section of restaurant – It illustrates how shading system and skylight work in summer.

Basically during summer time the horizontal overhangs are more effective, especially at midday time, so they let diffused sunlight passing through. Early in morning or late in the evening when sun is lower in the sky, adjustable vertical louvers can avoid or let more light coming inside. As mentioned before they won't make any incontinence for people's visual connection with outside. The skylight openings are also a great help to increase the level of daylighting in the central part of restaurant.

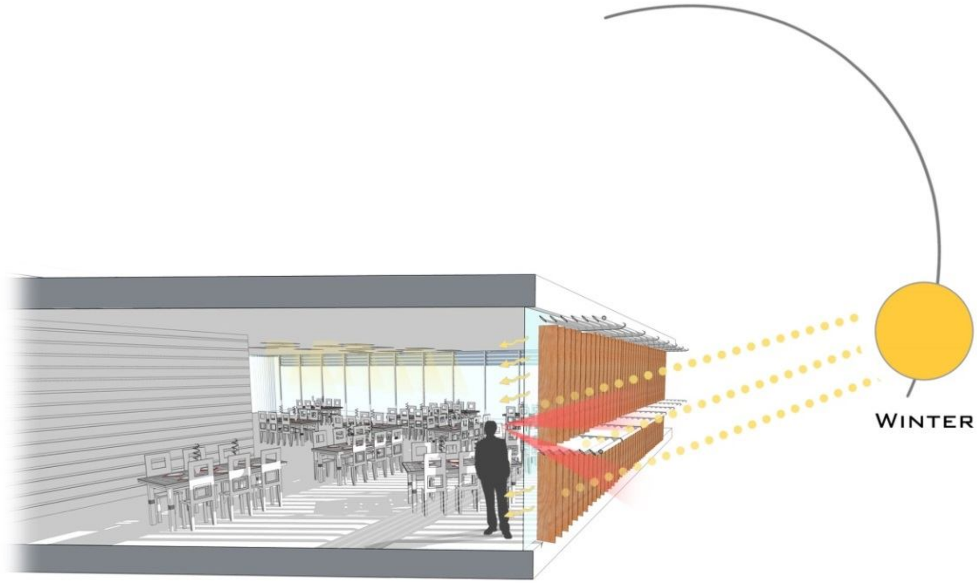


Figure 7.21: A section of restaurant – It illustrates how shading system and skylight work in winter.

For the winter time, when sun position is lower and sun rays have lower angles, day light can easily pass through the glazing. Even in this case, with the help of movable louvers, the management of restaurant can automatically control the amount of sunlight coming inside. Undoubtedly skylights are beneficial also in these times of the year.

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