Urban Refrigerator

Participant Name: Taehyun Jeon
Student Number: 90984578 0
University Name: Harvard University

Project Abstract

The project creates an urban-scale cooling device, which utilizes available natural sources of energy, such as wind and water, to control micro-climate conditions of a tropical living environment in sustainable and scientific ways. This is based on not only existing environmental factors, but also interactions between urban contexts, so that it builds up a sort of artificial ecological system, as an advanced way of urban co-existence in a tropical region. Specifically, this project consists of residential blocks of natural cooling and ventilation system, and provides cooled air to surrounding residential district and public park. As this project also provides pedestrian with semi-outdoor and landscape spaces as public domain for community purpose, Joo Chiat/Katong District and the East Coast Park are interlocked across the project site to integrate various cultural and public activities.

Urban Analysis

Transition as Medium

The project site is located between Joo Chiat/Katong District and the East Coast Park, and creates interconnections in-between. The site performs as a filter to provide transitional circumstances, from Joo Chiat/Katong to the East Coast Park, both in physical and cultural aspects. Traditionally existed issues in this place, such as old and new, natural and artificial, cultural mixes, etc., have been transformed into reciprocal interactions in terms of sustainability through this project.

Local Context

As exploring the answer for a feasible way of tropical living in a city, urban contexts in Joo Chiat/Katong District, where is historical and residential conservation area, have been reexamined. Architectural traits of Joo Chiat/Katong were focused and translated into an architectural system, as an experimental solution for a new tropical architecture.

Vernacular Architecture Analysis

Tropicality in Architecture

Based on architectural investigations in Joo Chiat/Katong District, it has been concluded that construction of semi-outdoor space with utilizing prevailing wind for natural ventilation and

cooling is predominant both in urban and architectural scale. They are clearly found from structural features of shophouse and private bungalow.

Shophouse Study

Shophouse is a common form of urban fabric in Singapore with mixed-use and residential purposes. In most cases, shop and food court occupy the ground floor of the shophouse, including some part of the five foot way. The five foot way is a certain type of canopied outdoor arcade of approximately 1.5m in width, which has been constructed to block strong sunlight and squall. And, the five foot way has potentiality of spatial and programmatic expansion.

Bungalow Study

Bungalow is a private housing, responding to the tropical climate. In a bungalow, living room is located in the center to be used for wind path and natural ventilation. The first floor of bungalow is raised to be distant from heat and humidity emitted from the ground, and underground storage space is used for heat buffer.

Framework

The five foot way from the shophouse and wind path from the bungalow are integrated into a basic element of an architectural system. Creating a breezeway-like structural module and its expansional combinations form a framework of the project, and correspond to tropical and local environmental conditions.

Climate Anaysis

Sun Path

In terms of the Köppen climate classification, Singapore belongs to the Rainforest Tropical Climate Region, with extremely hot and humid climate conditions, as located on the equator. Sun paths in Singapore have straight trajectories over the ground. Accordingly, sun light here is something to be blocked, rather than to take into a building, for a comfort living condition.

Prevailing Wind

In Singapore, the prevailing surface wind blows from the North-East, and the wind speed gets stronger during daytime. Interestingly enough, sometimes the prevailing wind blows from the North-East, and other times from the South-West, back and forth. As strength of the wind is under 1m/s, not strong enough, design solutions to increase the wind speed to make it enough for natural cooling are required. Given this, wind path space aligned on the North-East to South-West axis and tapered spatial configuration to increase speed of the prevailing wind are come up with for the aforementioned design solution.

Thermal Strategy

Heat Contact and Exchange

Generally, heat in a space is stagnant, but in a tapered space, spatial volume near ceiling is much smaller, and thus easily cooled by chiller surface, and then it creates convection and makes thermal conditions in the tapered space close to the ideal condition.

Prototype Design

Heat Transmissive Box

Modules of the tapered volume, generated from the five-foot way framework, are connected and stacked to form the entire structural system. When it comes to the design process, first, the perimeter layer encircles the top, bottom and the East and West sides of the building to block heat from sunlight and ground, and at the same time, the sides of this layer are porous with waffled structure on an axis angle of 45 degrees to make prevailing winds passing through the perimeter layer. On top of that, this layer is composed of metal plates to transfer heat quickly all the way down to underground cooling system for water-based natural cooling by heat exchange. And, an additional perimeter layer of folded surface beneath the top is created, where the outer and inner structures contact, and then rotated to 90 degrees to make it perpendicular to the outer later to make heat contact surface pointed. The inner structure is tapered and contains water inside to cool interior spaces, and then circulate and re-cool the water by having the used water pass through underground water channels with a low constant temperature.

Collective Housing Design

Masterplan Strategy

Wind Path

Five Collective housing blocks with 60 households each are deployed on the separated North-East to South-West Axes, to take the prevailing wind and make it path through the block with no interference to each other.

Vapor Layer

The locational advantage of being adjacent to the sea is that it is easier to take stronger breeze in the coastal area and to utilize the sea water. Reservoir as artificial ponds, filled with filtered sea water, create vapor layers between housing blocks, to enhance performance of cooling effect of the prevailing wind by reducing air temperature.

Collective Housing Block Design Process

This phase is a design implementation of the tropical collective residential architecture, integrating investigations from the former analysis and prototype design. Basically, the building is

covered by a sun protective layer, and openings are facing to the North and the South. To make more areas take prevailing wind, building modules are shifted by creating wind path situated on the North-East to South-West Axis. They are shifted again in a way to create terraces toward the public park and the sea. Vertical cores are installed as a structural support, and heat transfer skin of metal claddings is formed to transfer heat gained during daytime, apart from the main volume. Vertical cores form in-between valleys for taking prevailing wind and increased prevailing wind speed.

Collective Housing Block and Residential Unit Plan

Two mirrored types of a residential unit (Type A/Type B) share one vertical core and variable common spaces, and each floor of the housing block has 5 vertical cores. Each residential unit has a large central living room with multi-purposed functions, where residents will spend most of their daytime, as a prevailing wind path on the North-East to South-West axis. There are 7 upper ground floors in one housing block, and residential units are placed on from the second to the seventh floors. The ground and the first underground floor are allocated for retails and public spaces, incorporated with surrounding landscape spaces within the project site. Long corridors on the ground floor within the vertical cores connect the public areas with elevators and staircases to each residential unit, and will be used for community purposes. The landscape paths complete an integrated pedestrian network, linking Joo Chiat/Katong District and the East Coast Park.

Water-Based Cooling System

Cooling Water Circulation System

Interior spaces of the housing block are chilled by cooling water pipes, forming the structural system of tapered shape, and once it has been used, the water circulates from upper spaces to the underground cooling system, and then gets re-cooled in there. The underground cooling system of water channels bundle is connected to the reservoir pond, with filtered sea water and constant low temperature below, to maintain cool water temperature in the channels.

Roof System

As for roof details, aluminum panels are installed as the most outer layer. Steel frames, waterproofing and insulations are situated below the aluminum panel layer. Structural frames consist of hallow stainless steel pipes to deliver chilled water for cooling and circulate the used water for re-cooling throughout the entire cooling system. By using gutter and furrow between folded panels, the roof system is able to create water layer above the roof for cooling at night, while the prevailing wind is relatively weak.

Façade System

Wedge-Shaped frame of waffled structure filters natural sunlight by blocking direct sunlight from

the East and the West and allowing indirect sunlight diffused inside spaces. Perforations of the façade system, parallel to the prevailing wind direction, provide natural ventilation, and the wind in and out is chilled by cool water inside the wedge-shaped frame by heat exchange, while penetrating through the facade.

Heat transfer Controlling System

Layered Material System

The building is composed of three heat-related systems, based on various heat transfer rates of building materials, such as heat transfer system, heat block system and water cooling system. The heat transfer system is composed of steel frame with aluminum cladding, and heat block system is composed of wood and glass finishes, and water cooling system is composed of stainless steel frame of water channels. As for exterior, steel frames are concealed by aluminum claddings, once the claddings gain heat, and then immediately transfer the heat gain to the underground cooling system. And, above the aluminum cladding, there are wooden floorings contribute to reduce heat gain to aluminum panels. As for interior, stainless steel water pipes form the main structure as slab and post, and the floor is finished by natural wood.