LIGHT SHADOW AND WIND IN BUILDING DESIGN

Preeti P. Katyarmal

Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Master of Architecture

Committee Chair  Jaan Holt
Committee Member  Paul Emmons
Committee Member  Marcia Feuerstein

December 18, 2008
Alexandria, VA

Keywords: Light, shadow, Wind, Bernoulli Effect, Venturi Action, Energy, Wind Escape, Wind Catchers, Badgir, Malqaf, Louvers, Brise-Soleil, Natural Ventilation.
Design is about understanding a space. It is about integration of light and air in building design. It is about light, shadow, reflection. It is about wind, its movement and escape.

Through designing this project I was able to explore how sun, wind and light can be used effectively in a building design, in my project, in an office environment.

The fire, the Light; the energy is the inspiration behind the origin of Architecture. Energy brings architecture into the world of processes and life and Architecture brings together Fire and Shelter, Chaos and Organization. Day lighting or the use of natural light in a building is one of the fundamental elements used to bring an essential experience of visual comfort and outside world environmental stimulation for all building occupants.

The History of Architecture, said Le Corbusier, is a history of the struggle for light, the struggle for the window. This thesis assembles the research, conceptualization and final development of the office building design with an integration of light and wind.
ACKNOWLEDGEMENT

I would like to thank

Jaan Holt, Paul Emmons and Marcia Feuerstein, my committee, for their guidance, Encouragement and support through the formulation of my thesis. Your analytical views greatly stimulated my thought process, and will continue motivating me.

Special thanks to Jaan for showing immense patience with me through my journey at WAAC.

my parents, my sister and my brother for their love and support. Without you I would not have reached this point.

my best friends for always being there to talk and cheer me up.

my friends in Blacksburg and Alexandria, Ryo, Grace, Hrishi, Sneha, Amit, Darshana and Manoj for all the bliss and love, which helped me, get through the long hours working on my project.
CONTENTS

Thought…the Light 1

I- LIGHT AND WIND
Literature Review

Study….. the Shadow 3

Site….. the Spot 12

II- DESIGN
Office Building

Program….. 17

Design development …. The reflection 20

Final design 27

Conclusion 51

References 52

Bibliography 53

Picture Credit 54

Vita 55
Histories of civilization often begin with the discovery of Fire. In the Roman coloris’ narrative about “the beginning of buildings”, it is the discovery of fire that gives rise to human society and with it the construction of the shelter.

1The warmth of the fire inspired Vitruvius to write, “the men of old were born like wild beasts, in woods, caves, and groves, and lived on savage fare. As time went on, the thickly crowded trees in a certain place, tossed by storms and winds, and rubbing their branches against one another, caught fire, and so the inhabitants of the place were put to flight, being terrified of the flames. After it subsided, they drew near, and observing that they were comfortable standing before a warm fire, they put logs on and while keeping it alive, brought other people to it, showing them how much comfort they got from it... therefore it was the discovery of fire that originally gave rise to the coming together of men, to the deliberate assembly, and to social intercourse.”

In the classical world of Greek and Romans it always had an utmost importance in their civilizations. The fire, the energy is the inspiration behind the origin of Architecture. Energy brings architecture into the world of processes and life and Architecture brings together Fire and Shelter, Chaos and Organization. The relation between the construction and fire is clearly reflected when architecture is developed to its most essential; the rituals of urban foundation and primeval form in which the infantile perception & analysis of house is implemented.

1-Thermal Delight in Architecture By Lisa Heschon, Page no. 11
Living organisms have evolved with their unique Ecosystem which is equipped with their own high-performance energy management structure to allow them to survive in various environmental conditions. They are not only efficient organisms in themselves; they have also developed technologies using renewable energy for their needs. Many birds use thermals to rise and stay in the sky just as a wind glider does.

The Albatross makes use of varying wind speeds and turbulence over the sea to reduce its metabolic energy consumption by using the principle of aerodynamics. The human body is a refined mechanism with certain basic requirements. The human senses are interactive with the environment. The performance of human skin is limited. In order to keep comfort in the natural environment humans created their own protection by creating clothing and buildings. They developed some simple building solutions, building forms and intelligent building technologies to maintain the comfort around them. Air movement plays a great role in sensing comfort in our life. To feel warmed or cooled we created certain conditions around us. Japanese used wind chimes which gives a suggestion of refreshing wind and coolness, Mughal’s technique of using water fountains inside the building allowed the users to enjoy comfortable shaded and cool spaces.
I-LIGHT AND WIND

Literature Review

STUDY...... THE SHADOW
As in much of Peter Zumthor’s works, the Thermal Baths at Zals is a space that stimulates all the senses. The use of light and materials creates not only a feast for the eyes, but also evokes rich experiences in taste, touch, hearing, and smell.

Fig. 1.1 Thermal Baths
By Peter Zumthor

The strong contrast between the light and the shadow gives a dramatic appearance to the space. The darkness is emphasized with the use of textures with the materials.

Fig. 1.2 Church Of Light
by Tadao Ando

In Ronchamp Le Corbusier has achieved a balance between interior space and exterior form of the building. The openings on the south façade are an example of his use of solar conception with precision considering the equinoxes and solstices.

Fig. 1.3 Chapel, Ronchamp
By Le Corbusier

Fig. 1.1 http://www.arcspac.com/books/zumthor/, Fig. 1.2 http://www.bdonline.co.uk/Pictures/336xAny/j/c/c/church_of_light_ready.jpg, Fig. 1.3 http://www.greatbuildings.com/cgibi/gbi.cgi/Notre_Dame_du_Haut.html/cid_1213221729_Ronchamp10.html
The thesis project was designed to utilize the Bernoulli principle of air movement by wind-generated pressure differentials. The theorem is, when air is channeled into the larger end of the funnel, it accelerates as it passes through, owing to the reduced open area through which the same volume of air must pass in the same period. The system is designed, in effect, the idea that forcing the same amount of air through a smaller space (the opening in the envelope) actually increases the wind speed thus creating more potential energy.

Fig. 1.4 The Commerzbank Building
By Norman Foster

Fig. 1.5A The Pearl River Tower
By SOM

Natural ventilation also influenced the building’s design - the operable facades create natural air ventilation throughout the entire structure. Since the offices in the building wrapped along both the exterior and interior facades, those on the interior needed to be provided with an ample exterior light source.

Fig. 1.4 http://web.utk.edu/~archinfo/a489_f02/PDF/commerzbank.pdf, Fig. 1.5A http://www.ecogeek.org/content/view/695/, Fig. 1.5B High Performance Buildings, A magazine of the ASHRAE Winter 2008
ARCHITECTURAL ELEMENTS

The architectural design can ensure natural air movement into building design through different elements based on different principles. The primeval architecture existed to create comfortable internal conditions, roofs, walls, floors, and doors all advanced through phases of time and developed to fit the climate.

The badgir or the Malqaf or Wind catchers which can be found in some parts of Asia, are developed to catch the cool air from any direction and channel into the living space below. Therefore in most of the cities in this area, the traditional homes are equipped with enormous wind catchers.

For ventilation purposes wind-catchers were designed to trap the wind from high above the building where it is cooler and stronger and channels it down into the building.

They are designed as a shaft rising above the building with an opening facing the prevailing wind. These wind-catchers are also known as Malqaf and badgir.

---

Fig. 1.6 Typical Badgir
Fig. 1.7 Section showing Maqaf
Fig. 1.9 Badgir
Fig. 1.6 Solar power: the evolution of sustainable architecture / Sophia and Stefan Behling, in collaboration with Bruno Schindler; foreword by Norman Foster, Page no.64, Fig. 1.7 http://www.unu.edu/unupress/unupbooks/80a01e/ 80A01E0K.GIF, Fig. 1.8 http://www.ullesthorpewindmill.org.uk/images/uploads/IranianBadGhir.jpg, Fig. 1.9 http://photo.net/photo/db/photo?photo_id=5578128
**THE MALQAF:**

The Malqaf looks like the sails capturing wind above the houses and used many of the dense cities. The size of the malqaf is much smaller than the building facade and is determined as per the external temperature and wind density. The hot air drafts from these inlets are then allowed to pass over an air cooling system to lower the temperature. One type of air cooling system utilizes the Bernoulli Effect with baffles of charcoal panels placed inside the malqaf.

**THE BADGIR:**

The Badgir is a shaft with top openings on two or four sides with two partitions placed diagonally across each other. These partitions go down the length of the shaft to catch the breezes from any direction.

Due to the Bernoulli or Venturi effect the air flow over and around the building produces a zone of low pressure in the courtyard. Thus the air from the loggia escapes into the wind to be continuously replaced by the air coming through the wind catchers. This ensures the steady airflow due to convection.

Fig. 1.10 Showing the Wind directions through the Badgir.

Fig. 1.11 Malqaf With Baffles and a Wind Escape.

Fig. 1.9 http://photo.net/photodb/photo?photo_id=557828, Fig. 1.11 http://www.unu.edu/unupress/unupbooks/80a01e/80A01E0S.GIF, Fig. 1.12 http://www.unu.edu/unupress/unupbooks/80a01e/80A01E0L.GIF
We are born of light. The seasons are felt through light. We only know the world as it is evolved by light. To me natural light is the only light, because it has mood, it provides a ground for common agreement for man......it puts us in touch with the eternal. Natural light is the only light that makes architecture architecture.2

THE OPENINGS:

The History of Architecture, said Le Corbusier, is a history of the struggle for light, the struggle for the window. It is not only an opening in the wall but the transparent part of the wall itself. Northern façade is least exposed to the sun and ideal for locating most usable rooms on this side. The advantage of openings on this façade is that the illumination is always evenly distributed as the sun’s rays are almost tangential to the surface of the wall. Southern façade can be shaded with relatively small overhangs which control the sun’s penetration during summer time and allow the sunshine to penetrate when the sun is low in winter. To maintain the airflow in the southern area there are ways of directing airflow to spaces either by architectural design or such devices as wind catchers and the wind escapes.

Fig. 1.13 Palace of Justice, Chandigarh
By Le Corbusier

Eastern light is usually soothing in the morning and the façade or the rooms along this side get cooler by the evening and the space become more habitable during the night as compared to western side. Western light is usually harsh in the evening and demands well designed sun controls.

THE BRISÉ-SOLEIL:

The Brise-Soleil is also known as a sun breaker which is a new shading device and is generally used to shield entire glass facades of glass wall, concrete or steel frame buildings. These are used to reduce heat gain due to interception of sun rays. It can also be used to deflect the wind downward into the usable area.

Fig. 1.13 Sun, Wind and Light: Architectural Design Strategies, By G. Z. Brown, Page no. 146
However it does have a disadvantage of blocking the view to the outside area. But it may be used favorably in some designs if comprehensively articulated in the façade with due regard for reduction of physical glare and for aesthetics.

Fig. 1.14 Mill Owners Association building, Ahmadabad, By Le Corbusier

Brise-Soleil are used as walls on east and west facades of the Mill-Owner’s Association Building in Ahmadabad. These walls are solving the purpose of shading and the curved ceiling reflects the light inside the hall to keep naturally lit.

Fig. 1.14 Sun, Wind and Light: Architectural Design Strategies, By G. Z. Brown, Page no. 147
The strategy of wind-catchers is used by Glen Murcutt in many of his designs. One of his buildings includes MINERAL AND MINING MUSEUM, in New South Wales. On three sides of the building he has designed zigzag walls which hold these types of wind catchers to maintain the steady airflow inside the building. The roof slope tends to create negative pressure on the leeward side of the building, triggering the air movement required for the system to work.

Fig. 1.15A Detailed cross-section sheltered by the main roof Maltqafs (fed with air cooled by beds of charcoal and water) determine the form of the walls to generate ventilation through the exhibition spaces.

Fig. 1.15B Lower level Plan showing the Zigzag walls with the wind catchers.
Luzern Culture and Congress Center
By Jean Novel

Cross section showing the main hall clad in colored wood

Fig. 1.16

View from the north bank of the lake

Fig. 1.16 Jean Nouvel: Luzern: concert hall = Konzertsaal = salle de concert /
Southwest Waterfront, located on east of the Anacostia River, is a part of L’enfant’s original plan of southwest Washington DC. It is the smallest quadrant of Washington’s four quadrants.

In the 1950s the Old Southwest quadrant was revitalized as per the Urban Renewal Plan. The distinctive street layout and housing arrangements reveal the astounding vision of urban planners and architects in that time.
I first visited the Southwest waterfront area as part of my art & urbanism class with Professor Susan Piedmont-Palladino. I instantly liked the surrounding environment and architecture. I started looking at this area for a potential site for my thesis project. The site that I have selected for the project is at James Creek marina, located at southwest waterfront area.

James Creek marina is located near the national defense university at Fort Lesley J. McNair. Other marinas which are located close to the newly developed southwest waterfront area are well facilitated as per the Urban renewal Plan. James Creek marina was earlier a part of army land and is not developed adequately as part of the developed waterfront area.
I wanted to retain the original function of the site as a marina. So as part of the program the thought emerged to develop the existing marina facility and provide additional office spaces and exhibit area for old boats. The waterfront of the site was an inspiration to develop my idea of bringing light and wind integration into my building. The play of shadow and the reflection give dramatic effect to the building.
The site is located between the imposing red brick Beaux Arts War College building on the west and the headquarters of the United States coast guard on the east. There is also a newly constructed Lincoln hall & convention center on the north.
II- DESIGN

THE PROGRAM
I was exploring different forms for the building to create a mass that forces wind to enter inside the building by creating wind tunnel effects.
To retain the original function of the site as the marina, the program includes marina facility, additional office spaces, Boat house museum, Office towers and Restaurant. The waterfront gave me an opportunity to bring water into my office building.

**PROGRAM**

- OFFICE
- BUILDING

**BOAT HOUSE**

- plaza
- foyers
- information center
- elevator lobby
- service areas M/E
- restrooms

**LOWER LEVELS**

- Elevator lobby
- foyer
- work area
- conference rooms
- meeting rooms
- office cabins
- storage areas
- kitchen
- restrooms

**UPPER LEVELS**

- plaza
- information center
- boat house museum
- marina office
- lobby

- yacht repair workshop
- fuelstop
- locker rooms
- fitness club
- storage areas
- restrooms
FIRST LEVEL PLAN  SCALE- 1"=60'

Conceptual Section
SECOND LEVEL PLAN
SCALE: 1" = 60'
N
THE WEST FACADE:
Shading devices are provided for the third and sixth floor on west side.

Fourth and Fifth floor are recessed inside, so that the upper level floor provides shading for the level levels.
The waterfront of the site was an inspiration to develop my idea of bringing light and wind integration into my building. The play of shadow and the reflection give dramatic effect to the building.
To maintain steady air flow pattern during summer, the wall along south-east is developed with an idea of using Malqaf, The Wind catchers.
THE WIND-CATCHERS:

The wind catchers are provided above the atrium to draw the warm air inside the building. The indoor air movement can be maintained by creating suction from low air pressure at lower level and higher pressure at the top caused by wind force.
IMPORTANT FEATURES OF THE BUILDING
Through this exercise I understood the relation of wind and light with building’s forms, structures, and the surroundings. By concentrating on the relation between conceptual phenomenological dimensions of architectural space with respect to Sun’s position and wind movements, we can explore and create an environment that complements and celebrates the presence and ever-changing nature of sun and wind.
1. Thermal Delight in Architecture by Lisa Heschon, Page no. 11
2. Studies in Tectonic Culture, by Kenneth Frampton, John Cava, Graham Foundation for Advanced Studies in the Fine Arts, Page no. 239
Solar power: the evolution of sustainable architecture / Sophia and Stefan Behling, in collaboration with Bruno Schindler; foreword by Norman Foster

http://www.unu.edu/unupress/unupbooks/80a01e/80A01E0c.htm

Thermal delight in architecture / Lisa Heschong

Fire and memory: on architecture and energy / Luis Fernández-Galiano; translated by Gina Carriño

High Performance Buildings, A magazine of the ASHRAE Winter 2008

Climatic design: energy-efficient building principles and practices / Donald Watson and Kenneth Labs.

Sun, wind & light: architectural design strategies, By G. Z. Brown

Big & green: toward sustainable architecture in the 21st century, By David Gissen

http://www.wbdg.org/resources/


Atmosphères: architectural environments, surrounding objects, By Peter Zumthor

Tadao Ando at Naoshima: art, architecture, nature, By Philip Jodidio.
All images unless otherwise credited are works of the Author.

“All photographs and images contained in the ETD have been evaluated, according to the four ‘fair use factors’ for copyrighted materials and deemed to be fair.”
PREETI P KATYARMAL

Aug 2006 - December 2008 Master of Architecture, Virginia Polytechnic Institute and State University Alexandria, VA, USA


RELEVANT EXPERIENCE

Intern Architect, Perkins + Will, Washington, DC  
As Design Team Member was involved in design development.  
Summer – 2008

Intern Architect, Cooper Carry Inc. Alexandria, VA  
As an Intern Architect was involved in construction documentation, for Ashby: Multifamily Residential Tower, McLean.  
Fall – 2007

Intern Architect, Zimmer Gunsul Frasca Architects, Washington, DC  
As Design Team Member was involved in construction document preparation and engineering design coordi  
Summer – 2007

Assistant Architect, Aijaz Hakim Architect, Pune, India  
Aijaz Hakim Architect is Pune’s renowned Architectural firm specializing in designing Residential, Commercial and Recreational spaces. As an Assistant Architect, I was involved in  
- Project management including client, consultant and site co-ordination,  
- Interior design, design development and execution drawings.  
- Architectural design and execution drawings.  
Jan 2004 – Dec 2005

Junior Architect, Madhav Joshi and Associates, Pune, India  
Madhav Joshi and Associates are involved in designing esteem institutes and campuses all over India.  
June 2003 – Dec 2003

Graduate Information Associate, GIC, Virginia Tech  
Providing customer services, administrative support and marketing services to Virginia Tech Graduate School customers.  
Aug 2006 – May 2007