UNDERSTANDING DAYLIGHT QUALITY IN HOSPITAL BUILDINGS: A COMPARATIVE STUDY OF DIFFERENT DESIGN APPROACHES

Bachelor of Architecture Research Thesis dissertation

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Submitted By

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Approval

The following study is hereby approved as a creditable work on the subject carried out and presented in the manner, sufficiently satisfactory to warrant its acceptance as a pre-requisite towards the degree of Bachelor of Architecture for which it has been submitted.

It is to be understood that by this approval, the undersigned does not endorse or approve the statements made, opinions expressed or conclusion drawn therein, but approves the study only for the purpose for which it has been submitted and satisfies him/her to the requirements laid down in the academic program.

Thesis Title: Understanding daylight quality in Hospital buildings: A comparative study of different design approaches

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Declaration

I, **Shalvi Kinjalkumar Shah, 19BAR209**, give an undertaking that this research thesis entitled "**Understanding daylight quality in Hospital buildings: A comparative study of different design approaches**" submitted by me, towards partial fulfilment for the Degree of Bachelor of Architecture at Institute of Architecture and Planning, Nirma University, Ahmedabad, contains no material that has been submitted or awarded for any degree or diploma in any university/ school/institution to the best of my knowledge.

It is a primary work carried out by me and I give assurance that no attempt of plagiarism has been made. It contains no material that is previously published or written,
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This research thesis includes findings based on literature review, study of existing scientific papers, other research works, expert interviews, documentation, surveys, discussions and my own interpretations.

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CHAPTER 1: INTRODUCTION

1.1 Background of research

a. What is daylighting?

Natural light may be quite helpful in setting up a comfortable environement, helping to regulate the body clock, enhancing attention, and producing a serene peaceful atmosphere. In addition to helping prevent the growth of mould or mildew in buildings since these spores flourish in darkness, it can lower the energy consumption of a building compared to artificial lighting (thinking future, n.d.). Usually, a building's interior recieves natural light from the outside through glazing like windows or other openings.

Fig 1: Daylight in a room

- The technique of managing natural light that enters a place through architectural considerations such as windows and other openings is referred to as daylighting (ARIPIN, 2007).

Fig 2: Daylighting in hospital rooms

Daylighting involves knowledge of the physical properties and charateristics of natural light in built space. Daylight quality in hospital architecture refers to the level, distribution, and quality of natural light within hospital buildings (Husein Ali Husein, 2020) .It is a crucial aspect of healthcare facility design as it can have significant impacts on

wellbeing and recovery of patients, as well as the performance and satisfaction of health care staff.

Hospital environments plays a crucial role in supporting patient healing, staff performance, and overall occupant satisfaction. Many studies have shown that exposure can decrease the need for artifical lighting, leading to energy savings and reduced operational costs for healthcare facility (Stress reduction in the hospital room: Applying Ulrich's theory of supportive design, 2014). The quality of daylight in health architecture is crucial as it can significantly impact the wellbeing and overall experience of patients, staff and visitors. Below mentioned are some key aspects related to daylight quality in health architecture (Esraa Samir Mahmoud, 2019)

Fig 3: Patient watching through windows

The specific needs of healthcare settings and implementing appropriate design strategies, healthcare facilities can provide optimal daylighting conditions, contributing to improved patient wellbeing, staff satisfaction and energy efficiency.

1. Health and wellbeing
2. Visual comfort
3. Biophilic design
4. Energy efficiency
5. Privacy and Confidentiality

Fig 4: People sitting and waiting surrounding courtyard

Fig 5: Skylight as an element of daylighting

Daylight quality in healthcare architecture plays a vital role in creating healing and supportive environments. By considering Natural light has significant effect on hospital architecture design. It has an impact on various parts of the design process including architects to analyze the layout and orientation of the structure to maximize the quantity of natural light entering room.

The position of windows, skylights and atriums is meticulously designed to maximize daylight entering the area, especially in patient rooms, waiting areas and common spaces (i.e. corridors, courtyards, lobby, etc.)

Natural light influences the materials, colours and finishes used in the facility. Lighter colours and shiny surface are frequently used by the designers to improve the distribution of natural light throughout the area. This makes the environment brighter and more welcoming for patients, employee and vistitors.

The presence of natural light effects the layout of hospital's many functional departments. (Joon-Ho Choi, 2011). To maximize access to daylight, patient rooms, such as lounges and cafe's are intentionally placed near windows or skylight to give vistas and natural light to inhabitants.

Fig 6: Proportion of openings spreading daylight

Architects construct places that encourage healing, comfort, and wellbeing for patients while enhancing the working environment for healthcare staff by introducing natural light into hospital architecture. This research aims to understand the daylight quality in hospital architecture and how it changes its design to incorporate more natural light. Also into several architectural design strategies for maximizing the quality of natural light in hospitals. This might include analyzing building orientation, the location and designing of windows, skylights, and light wells, as well as selection of matrials and finishes that improve natural light dispersion and reflecting it back.

1.2 Research Questions

1. What are the key design principles and strategies for incorporating natural light in hospital architecture and design?
2. How the natural light is manifested in hospital design?
3. What is the quality of daylight in architecture?
4. What are the elements of architectural ways in which daylight can be incorporated?

1.3 Aim and Objectives

Aim is to compare different design approaches and their impact on daylight quality in hospitals.

1.3.1 Objectives

- To explore the relation between daylight and hospital designs.
- To understand the strategies of incorporating natural light as a significant factor in hospital designs.

Fig 7: Modern designed buildings having daylight

• To understand the manifestation of natural light in hospital designs.

1.4 Significance of Research

There are many researches done on natural light in hospitals and how it affects physcologically. But there is very less research done on how natural light affects the hospital spaces architecturally and how the light has been manifested. Also, many hospitals have not followed the minimum requirement or g overnment standards in hospitals. Hence, proving the standards would help architects and designers to incorporated more natural light in health care spaces. This research focuses only on the common spaces of hsopitals. The methodology established in this study could further be used to understand the change in the overall character of common spaces due to the character of natural light.

1.5 Scope and Limitations

Within wide scope of Biophilia this research focuses on the natural light in hsopital designs. It specifically understands the daylight quality in hospital buildings. Main focus would be on common areas and circulation sapces in hospitals as well as the majority occupied common spaces throughout the day. This paper specifically looks at the built envi-

ronment and role of daylight in designed healthcare spaces and also looks at design principles which enhance the incorporation of daylight in healthcare spaces.

- This research is only focused on natural light in hsopital building.
- It focuses on natural light and does not examine the effects of artifical light on the hospital environment.
- It only considers hospitals with a maximum of 500-600 beds, which limits the generalizability of the findings to larger hospitals.
- This research does not investigate the impact of natural light on patients and healthcare workers in individual patient rooms, operating rooms, or other specialized areas.
- It also does not explore the use of natural light in specific hospital departments or units or wards.

1.6 Methodology and framework

A comparative study analysis will be used to assess the effects of various daylighting design options on hospital architecture. This study will examine at least 3 hospitals with the varying designs. This research will focus on both qualtitative and qualitative aspects of light. The quantitative data will include the measurements of the amount of natural light and

Fig 8: Comparative analysis of case studies

how it is modulated to reach inside a space, as well as factors of orientation, porosity, and opening ratios in the hospitals chosen. Interviews within hospitals atff, architects and patients will be conducted to gain their opinions on the impact of various daylighting design concepts.

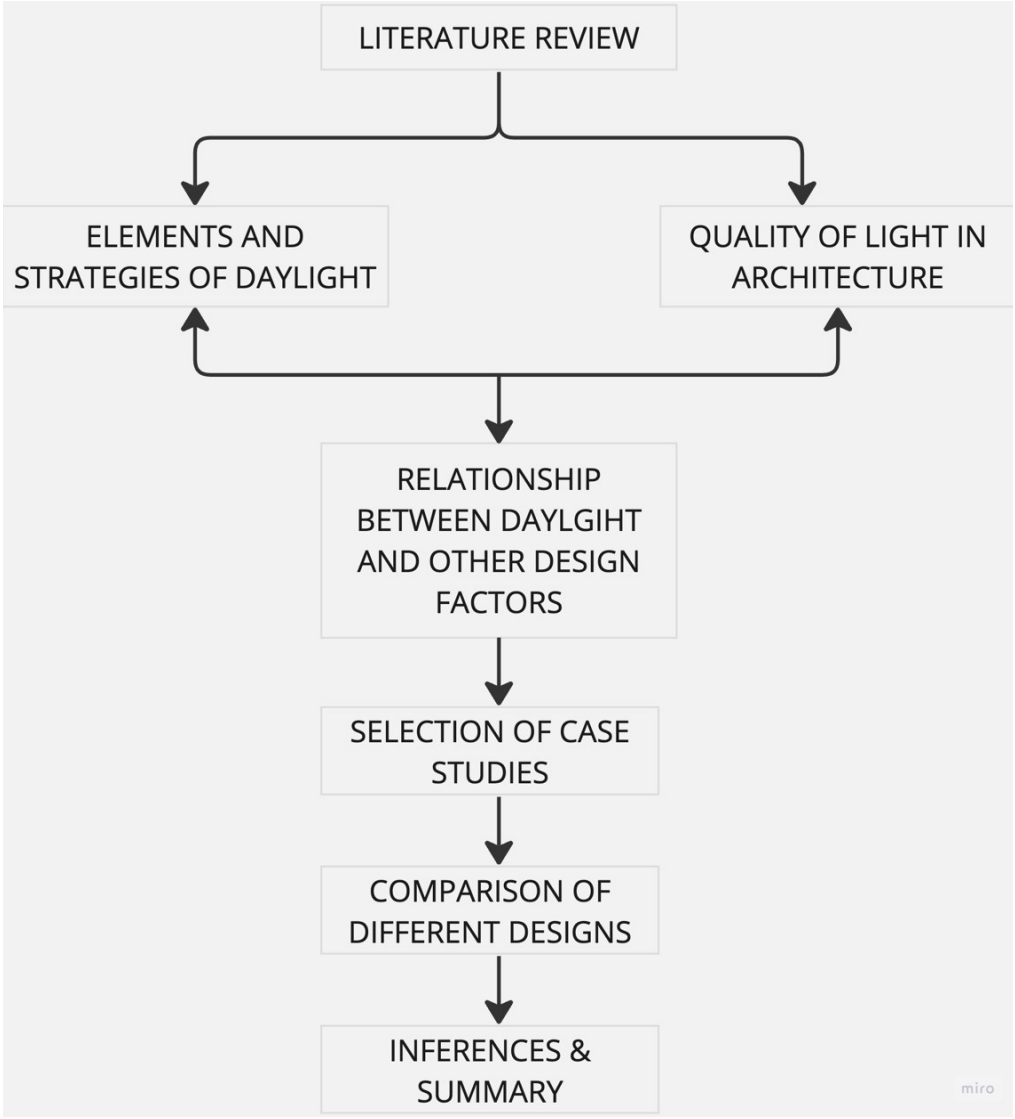

Fig 9: Framework of research thesis

CHAPTER 2
OVERVIEW & EVOLUTION

2.1 Natural light as a phenomenon
2.2 Historical antecedents of Natural light
2.3 Natural light and architecture

Chapter 2: Literature review

2.1 Natural light- Overview and Evolution

2.1.1 Natural light as phenomenon

Natural light is the most important element in the universe. It is prerequisite for all huma activities and is planned phenomenon for our survival on planet earth. Human life correlates with light since historic times form sunlight to moonlight to candlelight to gaslit streets, electric bulbs and now industrial light (Joon-Ho Choi a, 2011). It is exhibited in various forms: thermalenergy, a part of the electromagnetic spectrum, a sight giver to the eye as an organ, an illuminator, as starlight, sunlight and moonlight, as a definer of time and much more. We may argue that natural light functions as a “time defender” in the same way as sunlight desines the day and stars and moonlight design the night (Lim, 2020).

Beacuse the sun is the primary souce of light and the worls rotates around it. These continual variations in time and light results in different effects on the similar place and thus changing environment patterns affects how we experience and view our surroundings (chepchumba, 2013).

2.1.2 *Intensity of light*

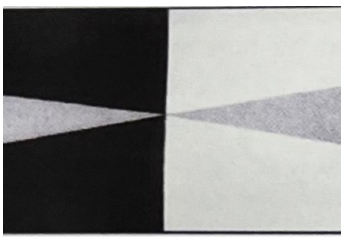

Fig 10: Grey triangles as intensity of light

Light intensity is an evulative feature of lighting that represents thw quantity of light that has entered. The brightness of the light source is governed by the perception of the creatures it tries to enlighten. A person can tell the difference between the brightness of an object and the brightness of its surrounds. (CURTIS, 1974) This indicates that brightness requires the use of two or more surface or objects, with one being more intense than the other. e.g. Assuming grey triangles have the same intensity level and measure of lighting, and so their perception will be affected by the brightness of the surrounding environment (Choi, 2015). Light creates certain conditions that can change the character of space due to its intensity, the way light is distributed throughout the space, and its qualities.

According to the varying intensities of light entering, space is rendered with certain qualities such as brillaint or dark, light or dull, pleasant or sad, dazzling or glaring (Prior, 1988).

2.1.3 *Direction*

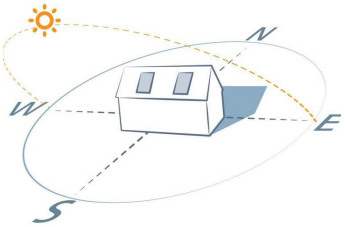

Fig 11: Direction of daylight during daytime

Our perception of light is based on understanding where it comes from. The source of light and the quality of light expected lend significance to its function.

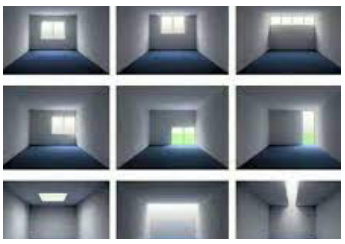

Fig 12: Proportion of openings affecting daylight

The general nature of space varies as the direction of incident light changes.

Natural light is divided into two types: sunlight and skylight. Sunlight is focused light that is directed in nature and moves according to the sun's path, whereas skylight is sunlight that is spread in the atmosphere and is diffused light. A 3D object is rendered depending on the direction of the incident light. In 3Dimensional situation, the direction of light is critical for 3D objects. The front light flattens the object's 3Dimentionality, whereas the side light highlights by the facial characteristics (Anna Louise Kragelund, 2016).

Besides this light flowing from different directions at the same time changes quality and creates a stability in contrast to that coming from single direction (Choi, 2015).

The quality and position of openings within an architectural space determine the openings. The direction of light effects the look of an item, does the direction of light falling on it.

Fig 13: Evolution stages of Light after Natural light

2.2 Historical antecedents of natural light

Natural light was the only source of light in ancient times. Human beings like natural light and want to have it in his home at all times. Light is as essential to human health as water and oxygen (Alobaidi,

2020).

Human beings used to dwell in the trees to get fresh air and sunlight. They retreated into a cave after descending from the trees to avoid the wild creatures, numbing cold, enervating heat, soaking rains and biting winds. Then they emerged in front of a cottage. The caves and houses lacked windows and were dark. There was no material available to keep the weather out while allowing light in. But as a light loving mammal human beings created a way to admit light. They initially introduced light into his home through the doorway, and then the roof's smoke outlet (Deema Amleh, 2023). It was the start of the century- long campaign of lights. Later, the primitive householder created a little window in the wall.

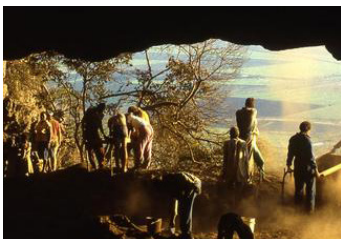

Fig 14: People during the stone age worked under natural light

The initial windows wall or roof openings, were built without covering or were covered with opaque materials like wood, woven thatch, rushes, leaves, or stone sheets, which were eventually covered with animal skins or fabric, preventing light from entering the space (Deema Amleh, 2023). These materials were gradually replaced with translucent marble, sheets or mica sheets ot parchment paper, oiled paper or oiled them.

Glass was eventually discovered, most likely in the

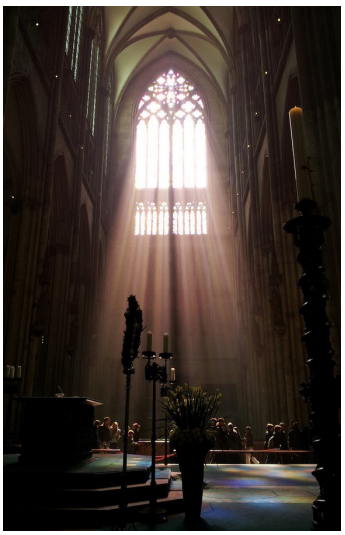

Fig 15: Windows as a source of light in church in history

second century before christ, and with its discovery, man gained an increasingly effective way of allowing light into his home (Chaham Alalouch, 2015).When egypt became a province of their empire, they learnt the manufacture of glass from the egyptians.

However, they exploited glass chiefly for decorative purposes; and its development was not sufficient to displace stone, cloth or shells entirely as a window covering because glass was a valuable commodity that only rich and powerful could afford. The church began to emply glass from windows throughout the early middle ages. Clear glass was blended with the small picies of colored glass to admit coloured light, genereating a holistic religious setting (Dicle AYDIN, 2018). However, the use of glass in household dwellings remained economically unattainable and distinct. When glass became commercially available and popular in the late sixteenth century, it bagan to be widely employed for domestic windows (CURTIS, 1974). However, It was just a brief success in the ancient fight for natural illumination, and the appropriate growth of natural lighting was limited and constrained by the window tax, which existed in Europe from 1695 to 1851. It was also limited in the 19th century by ar-

Fig 16: Stained glass evolution to get diffused light into church

chitects deliberate rejection of its technical possibilities and their different styles.

Since, late victoria era, a growing appreciation of the scientific principles of admitting daylight to building has gradually influenced architectural design. (Husein Ali Husein, 2020).

Architects have been able to emply as much as daylight as they like till the seventieth century (Bates, 2018) .Only in last century was daylight in architectural design explored systematically (Alexey Danilov, 2019). Architects and engineers investigated many techniques of supplying appropriate illumination, discovering certain mehtods to calculate daylight. After second worls war, the study of daylight in England and America beacame quiet progressive.

The use of daylighting in architecture dates back to ancient times and has a long and rich history. Architects have always recognised, from the use of natural light in determining the use of skylights in Egyptian pyramids to the stained glass windows of medieval cathedrals (Ar. Ankita satish taware, 2020). Natural light has played a significant role in indian culture and architecture since ancient times. In traditional Indian homes, natural light was often the primary source of illumination. The use of courtyards and open spaces allowed sunlight to penetrate deep into

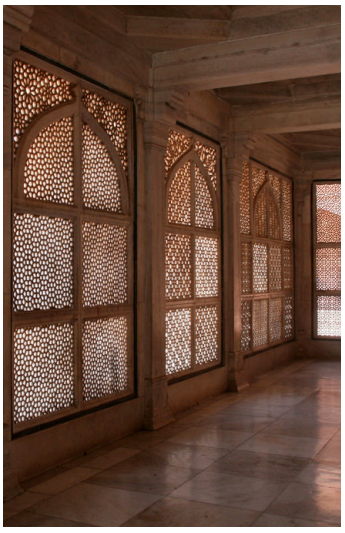

Fig 17: Invention of Jali's in Mughal era to incorporate natural light

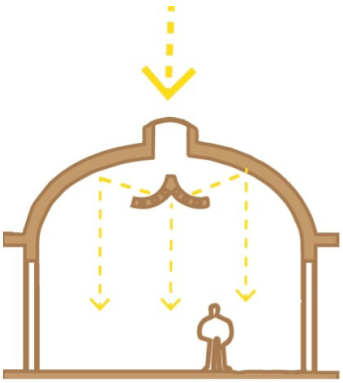

Fig 18: Louis Kahn's Kimbell Art Museum

the interior of the home, creating a warm and welcoming atmosphere (Esraa Samir Mahmoud, 2019). During the mughal era, natural light was used to enhance the beauty of architectural structures. The use of intricate jali screens and marble lattice work allowed the sunlight to filter through, creating stunning patterns of light and shadow. Hence, daylight has been evolved much since ancient times.

Now in modern times, the notable architects retained many of the historical principles of site orientation, natural ventilation and daylight illumination while selctively incorporating the new technology (Man Young Park, 2018).

- Frank Llyod Wright
- Louis Kahn
- Alvar Aalto
- Le corbusier

2.3 Natural light and Architecture

The introduction of technology has resulted in economic growth and social advancement, as well as fast industrialization and modernization. How to accomplish rapid growth while maintaining social peace and a sustainable environment and resouces has emerged as a fundamental challenge that world must address. In order to archive the sustainable development of the environment, it is imperative

to thoroughly discuss the use of natural light in architectural design and construct a systematic design concept and design methods (Shipra Kumari, 2020).

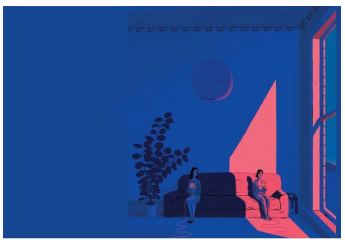

Fig 19: Active nature of humans when in natural light than in dark light

- Natural light helps people to use ledd air conditioners and coal while also adjusting the indoor temperature.
- Natural light aids in changing the aesthetic impact of structures. People are becoming more imaginative in architecture design as the building sector develops. As a result, in the past few decades, individuals have increased their utilization have increased their utilization of natural light, making urban structures more appelaing to people (Lisa Voggenberger, 2022).
- It also helps to preserve resources and energy. As natural light in the building and people's utlization rate of resouces and energy which results into energy savings and protection of environment (Jaja Thaddeus, 2021).
- Daylight is the practice of incorporating natural light into the design of a building.
- This involves strategic placement of windows, skylights, lightwells, and other openings to allow sunlight to enter the interior spaces.
- Daylighting can significantly reduce the need for artificial lighting during the day. It also creates a

Fig 20: The bigger the openings more the natural light

pleasant and visually comfortable environment for the users.

- It provides connection to the outdoors, offers different variations in light intensity and color throughout the day.
- Daylight is a combination of direct and indirect light sunlight during the day. It is a powerful architectural tool.
- It is a controlled use of natural light ina dn around buildings through the planning of windows, skylights and other openings and reflective surfaces.
- The purpose of daylighting is to gather light as much as possible to assist heat the building in the winter and enough light in the summer to switch off electric lights. In order to minimize the neagtive effects of the built environment in sustainable buildings (Iyendo, 2014).
- It is a powerful human link to nature, and thus daylight has a vital influence on human health on physical, physiological and psychological levels. The effective value of daylight will depend on the architectural design.
- The design aims to get more natural daylight to reach inside a building. The subject of daylight is extensive, for eg. It is related in fields of physics, medicine, biology, health, chemistry and environment.
- In our field of architecture, it is relevant in terms of energy consumption, but also it isa fundamental key factor for everything we build and design.
- Daylight affects everything we perceive; shape, color, surfaces, spaces.

CHAPTER 3
QUALITY OF LIGHT

3.1 Brief on quality of light in architecture
3.2 Daylighting in hospital architecture
3.3 Design strategies and elements of daylight
3.4 Relationship between openings and natural light

Chapter 3 : Quality of Light

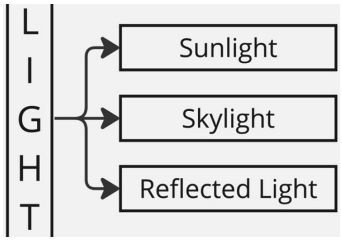

Fig 21:Qualities of Natural light

3.1 Brief on Quality of light in Architecture

- Daylight is also important for its quality, spectral composition and variability. It provides high illuminance and permits excellent color discrimination and color rendering. These two properties mean that daylight provides the condition for good vision. Effect of daylight on the performance of tasks depends on how the dayligth is delivered.
- The spatial atmosphere is determined by how elements in space interact with light. To understand this, we must learn about the characteristics of light that influence the nature of space (Lorissa MacAllister, 2017).
- The general character of space is determined by the positionof light source and its distribution in relation to the primary activities, surfaces and objects.

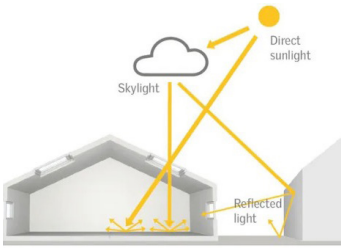

Fig 22: Diagram showing sunlight, skylight and reflected light

- Natural light has distinct properties that have been interfied by researchers as: Orientation, Intensity, mystery, shadow, contrast, color and variation.
- Light enters a place in a variety of ways, includ-

ing direct sunshine or harsh light, skylight and diffuse light, external reflected light and internal reflected ligth from room surfaces.

- As a result, the character of space at different times of the day and under different quality of light it is examined in order to gain a better understanding of the function and character of space in connection to light.
- The quality of light refers to the hardness or softness of light.
- Daylight in buildings is made up of direct sunshine, diffuse skylight, and light reflected off the ground and surrounding things (Neeraj Garg, 2016).

3.1.1 Sunlight

- Light from the sun is intense and directional. It is distinguished by its great intensity and continous movement in relation to the sun's path.
- The brightness of direct light varies based on the seasons, time of the day, location, and sky conditions.
- Specular light is light that consits of parellel rays of sunshine, such as beam of sunlight, and has an extremely sharp and harsh character.
- It can produce harsh highlights and throw shadows. It is strong and sharp, both in color and

Fig 23: Natural light coming through windows also called sunlight

temperature (Nishesh Jain, 2021).

- From the autumnal equinox until the spring equinox, there is no sunlight on the north facing wall of north-south hemispheres at the latitudes north of the tropic of cancer and south of the tropic of capricon (S G Abo Sabaa, A Study of Biophilic design and how it relates to the children's hospitals design, 2022).
- Any building design is required in hot environment, with careful control of allowances, diffusion, shading and reflection. It is directed in character and lends shape to construction form.

Fig 24: Skylight as a main source to invite natural light

3.1.2 Skylight

- Skylight is defined by sunlight that has been broken up and distrubuted by the atmosphere and clouds, producing soft gentle and diffused light. It can sometimes distort the impression of 3 Dimensionality of shapes (Lim, 2020).
- Lighting that is extensively dispersed across a large region has the tendency to flatten or decrease spatial perception/ experience.
- Skylight illuminated spaces changes with the seasons. It might be the similar in all orientations. Both in color and temperature, it is soft and cool. It provides energizing clarity when properly lighted.

Fig 25: Skylight in General wards

- It represents solid shape and emphasizes textures. Uniform or even lighting emphasizes all items equally and uneven lighting suggests direction of the eye.
- Reflected light rays disperse in all directions over a rough surface.
- Reflected light rays on a flat surface all go in the same direction. It is impacted by surface color, kind and texture, in some densely built up areas, light reflected from the ground and surrounding area can be significant contributor to daylight supply within the built spaces (Moamer M. Gashoot, 2022).

Fig 26: Skylight in corridors in hospitals

3.2 Daylighting in Hospital Architecture

Health care facilities are among the most expensive buildings to construct, maintain, operate, once built, hospitals remain in service for decades and are difficult to modify (phillips, 2004). Creating a healing environment with suitable physicl charateristics is vital to sustainable design in hospital buildings, as patients seek medical treatments and staff provides continuous support.

However, restoring health and wellbeing is more than just a question of physical secience.

The concept of healing environments was also treated and documented by florence night angle about

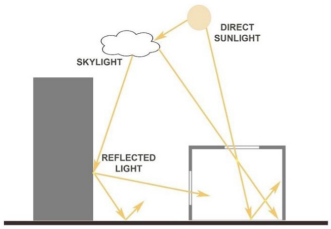

Fig 27: Sources to invite daylight

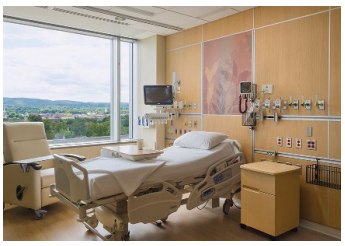

Fig 28: Large openings in hospital rooms

200 years ago, when she discovered that patients would recover more quickly from illness if they were cared for in and environment taht has natural light, ventilation, cleanliness and basic sanitation (Prior, 1988).

Healing environment is now the emphatic expression of the 21st century hospital design to promote patient, family, and staff satisfaction or comfort. (Shipra Kumari, 2020)

The concept of a healing environment reveals that the hospital environment can make a great difference in patient recovering. (Julie Bernhardt, 2021)

Daylight plays a significant role as one of the physical aspects in creating a healing environment.

It has a profound effect physiologically, mentally and psychologically on the human beings. (Lorissa MacAllister, 2017)

Orientation is an important consideration in the early stages of hospital architecture. Infact, might be claims that this is the most important consideration in the design priority for producing a sustainable hospital environment.

In hospital architecture , where the majot focus is providing a healing environment, the orientation of the structure influences the design of the windows, directly altering the quality of daylighting and ac-

cess to outside views. It would have major influence on the user's satisfaction.

Providing patients in ward surrounding access to outdoor views through windows would give them a feeling of direction and connection to the outside worlds. In the healing environment research community, there is an increasing agreement that the window is one of the most importance phycial components for patients and medical personnel physiologically, psychologically and mentally (Kaheneko, 2021).

Windows provide two benefits: one is natural light and other is view. A well designed window is a difficult endeavor that involves rigorous architectural, environmental, and cultural considerations. In research conducted surveys conducted in a hospital environment on access to natural light, 70% of the medical staff rated the increase in natural light as having a positive impact as having a positive impact on their work life (Qu Wang, 2018). Most areas in hospitals require natural daylight. Moreover, daylight is generally recognized as a part of the healthy environment.

Moreover, daylight is generally recognized as a part of the healthy environment.

In hospital design, daylight is utilized in many ways, such as the use of large windows and skylights, clerestory windows and large atriums. (Beth Murray-Davis, 2022)

Architectural daylighting is a branch of architectural physics that deals with natural light in structures. Its objective is to provide optimal lighting in a room to fulfill all the requirements for effective

visual work and healthy settings.

In practise, better utlising the constant natural light will save millions of power. However, the most significant criterion for delivering natural lighting in building in buildings are not only affordable but cheap.

Because man has evolved to live in an environment with natural illumination, lighting is essential for human physiological and hygenic well being. Natural light has a great impact on the shape of structures. The amount of natural light influences the deign, elevations, interior decor, and color choosing in many buildings.

3.3 Design strategies and elements of daylight

There are various daylighting techniques and strategies are available to professionals in the architectural field which includes:

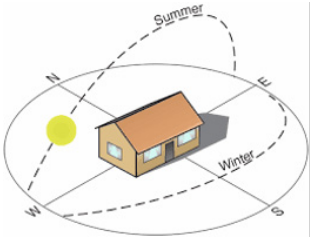

Fig 29: Building Orientation

- **Building Orientation:** Architects and designers may significantly boost natural light penetration into the interior rooms by carefully orienting a structure to absorb sunlight effectively.


Fig 30: Window design

- **Window design:** The size, shape and positioning of windows are essential factors in maximizing daylight penetration. Low- emissive coatings and electrochromic glass can also help regulate the quantity of sunlight that enters a building.


Fig 31: Light Shelves

- **Light shelves:** These horizontal overhangs, which are normally installed above eye level, helps in the reflection of natural light into interior areas while decreasing glare and direct solar heat gain.

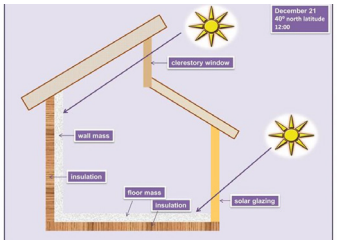

Fig 32: Clerestory windows

- **Clerestory windows:** These windows which are located high on the walls, allows sunlight to penetrate further into the building, giving indirect, diffuse light without producing glare or heat gain.
- **Skylights:** These daylighting solutions provide natural light from above, illuminating places that may not have access to windows or any other sources of light.
- **Solar tubes:** These systems collect sunlight

Fig 33: Solar tubes

from the roof and route it through reflecting tubes, dispersing it equally across interior rooms.

3.3.1. Elements of Daylight

Elements of daylight refer to the different components and characteristics that contribute to the presence and behavior of natural light within a space. The elements include:

- **Sunlight:** The major source of natural light is sunlight. It helps to the aesthetic and atmospheric aspects of a room by providing illumination and warmth. The direction, intensity, and colors of sunlight entering a structure are influenced by the sun's location and movement during the day.
- **Sky conditions:** The amount and quality of-daylight are affects by the sky's state such as whether it is clear, cloudy, or overcast. Clear skies enable direct sunlight to penetrate an area, but cloudy or overcast skies produce diffused light with less direct illumination but more even lighting.
- **Daylight patterns:** The variations in light intensity, directions, and distribution that occur during the day and throughout seasons are referred to as daylight patterns. The angle of the sun, the position of the structure and the surroundings have an impact on these patterns. Understanding daylight patterns may assist architects in optimizing window

location. shading devices, and interior design in order to capture natural light.

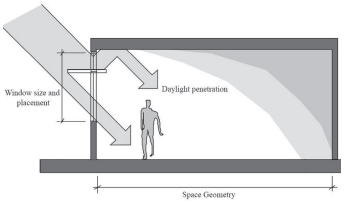

Fig 34: Daylight penetration

- **Daylight penetration:** Daylight penetration refers to the inside depth to which natural light can reach into the interiors of the building. It is impacted by variables like window size and its locations, the direction of the building, and the presence of neighboring structures or natural objects that may obstruct or reflect light.

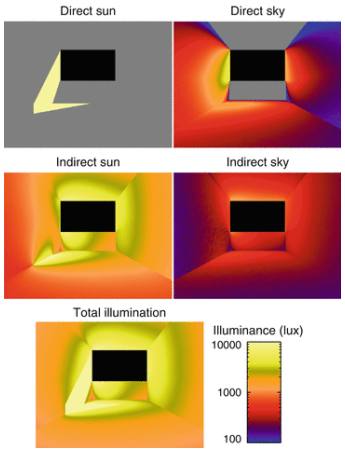

Fig 35: Illuminance in a room

- **Illuminance:** It is a measurement of the quality of light that falls on a surface and is usually represented in lux or footcandles. For visual comfort and activities need differing levels of illuminance. When planning daylighting methods, architects evaluate illuminance needs to provide acceptable light levels in specified regions.
- **Light distribution:** Natural light inside a room relates to how evenly or irregularly the light is distributed across different locations. The size, shape and position of windows, as well as the presence of interior features that may divert or dilute in light, all have an impact on it.

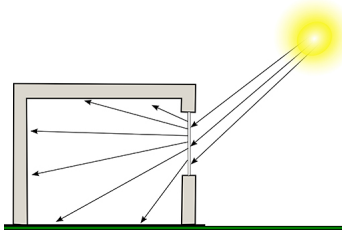

Fig 36: Daylight Distribution

3.4 Relationship between openings and natural light

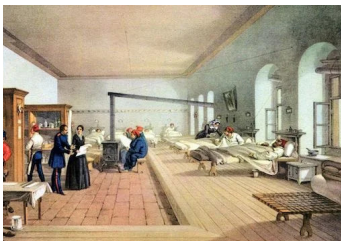

Fig 37: Windows in olden times in hospitals

The window is an opening in a closed container that offers outside view. Windows should be sized and placed so that they are at eyelevel for building inhabitants.

There are various methods for reducing solar gain in hot climates like Iraq (shading systems, installations of collector windows and double skin facades and use of heat control glass).

Wall-to-window ratio (WWR) is a significant factor impacting a building energy efficiency.

The number of windows will affect how the building is heated, cooled and lit as well as how it interacts with outside world in terms of views, ventilation and access to daylight.

NBC Standards for daylight	BIS Standards for daylight in hospitals	
8000 Lux for composite climate	Service Rooms	Min 200 Lux
9000 Lux for tempered climate	Wards	Min 150 lux
105000 Lux for hot- dry climate	Corridors	Min 150 lux
6800 Lux for cold climate	Patient room should recieve natural light through windows within area of 1/8th of the respective floor area of the respective room.	
	Minimum of 2% of the floor area of a hospital should be skylights to provide indirect natural light.	

Table 1: Government standards for Daylighting

- According to ASHRAE standard 55-2017, recommends that the average daylight illuminance in occupied spaces should be at least 300 lux (28 foot candles) and the maximum illuminance should not exceed 3000 lux (279 foot candles).
- Additionally, the standard recommends that daylight should be used to supplement electrical lighting in occupied spaces, with electrical lighting used as a primary light source only when the daylight is in sufficient.
- There is possibility of natural light building but hospital is a complex where maximum area is ocupiesby OPD and patients waiting in wating area.

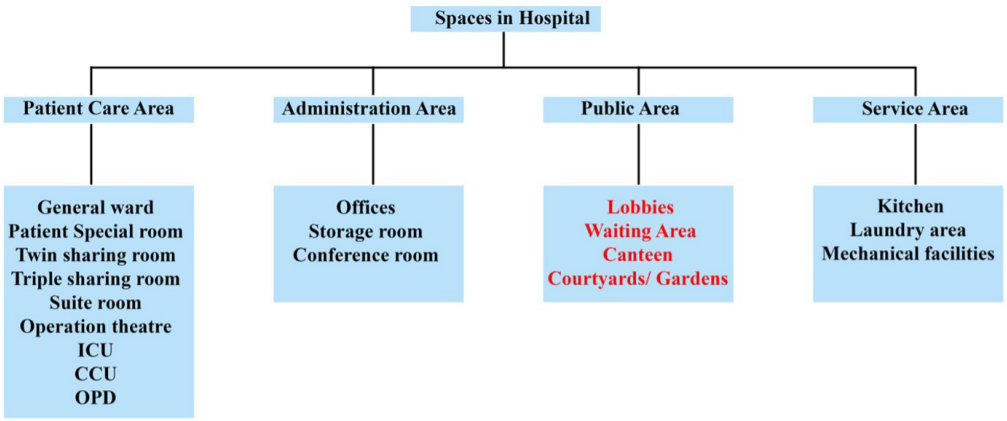

Fig 38: Highlighted are the spaces focused in this research

CHAPTER 4
CASE STUDY ANALYSIS

4.1 Criteria of case study selection
4.2 CIMS, Ahmedabad
4.3 S.D.M , Dharwad
4.4 Riviera- Chablais Hospital, Switzerland

Chapter 4: Case studies

4.1 Criteria for case study selection

Natural light as an element is used in building since ancient times. Several architects and designers have tries to incorporate natural light in several hospitals. But the requirement of natural light is being

increased as doctors, patients, staff and visitors feels the change when they are under a natural light.

To understand and analyze the quality of natural light present in the hospitals 2 cases in India have been considered.

These cases have been designed by different architects. To connect them there would be a comparison in between them where which case study has more natural light and which has better planning which will lead to meaningful conclusions.

Main criteria for selecting the Primary case studies area:-

- Restricted to general hospitals having minimum to maximum amount of natural light.
- It is limited to 500-600 bed hospital.
- Selected case studies should have sustainability or have any concept of green building.
- All selected cases have multiple courtyards within the building.

Case 1: CIMS (Clinical Incident Management System) Hospital, Ahmedabad

Fig 39: CIMS entrance

Architect: Ar. Surya Kakani

Site area: 10,000 sqm.

Established Year: 2010

Architectural Style: Contemporary Architecture

Inspired from: Traditional Courtyards

Floor Height: 3.6m clear height

Size: 350 beds

- This hospital is known for offering patients from all around India and intenationally.
- Cims Hospital is also called a green building.
- The ICU and the OT, the darkest spaces now have natural light.
- All the four blocks are seprated but are connected by the courtyards.
- This practices aim to reduce the environmental impact of new buildings.
- Internal courtyards are provided for natural light. In the middle of the building, reducing use of artificial lighting during the daytime even in large floor spaces.
- Gardens within the hospital acts as a fresh source of natural oxygen.
- The inclusion of skylights and gardens in the ICU and CCU areas is a first of its kind initiative in

Fig 40: Satellite image of the hospital

Asia, showcasing the project's commitment to innovative and thoughtful design.

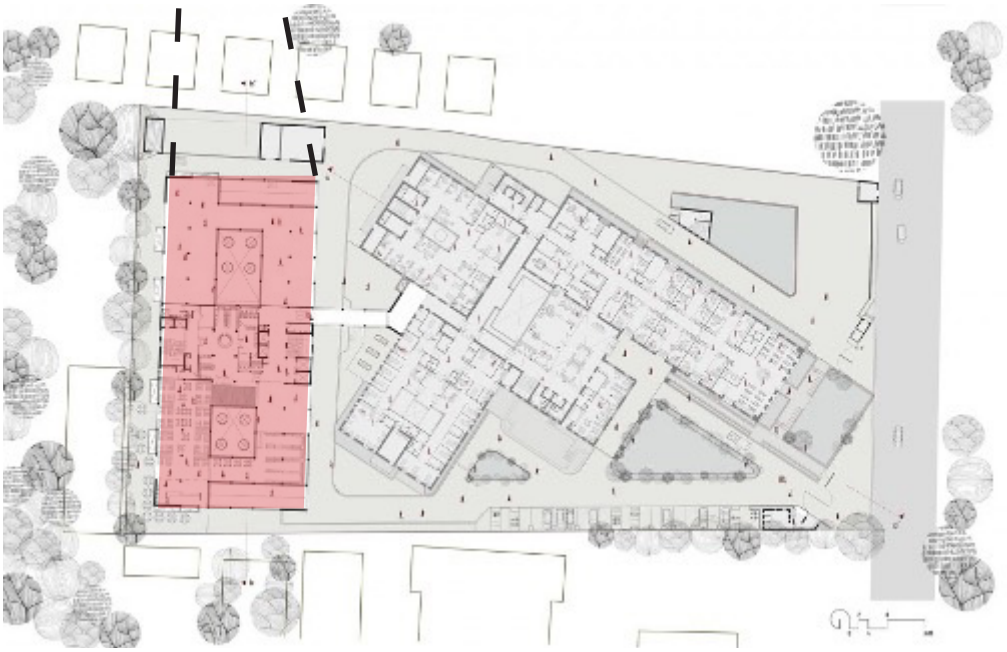

Fig 41: Location of CIMS East block

Fig 42: Spatial Organization

East Block Area Calculations		
Ground Coverage	Open Area	Built-up Area
2401.73 sqm.	310.04 sqm.	2091.69 sqm.

Table 2: Area calculations

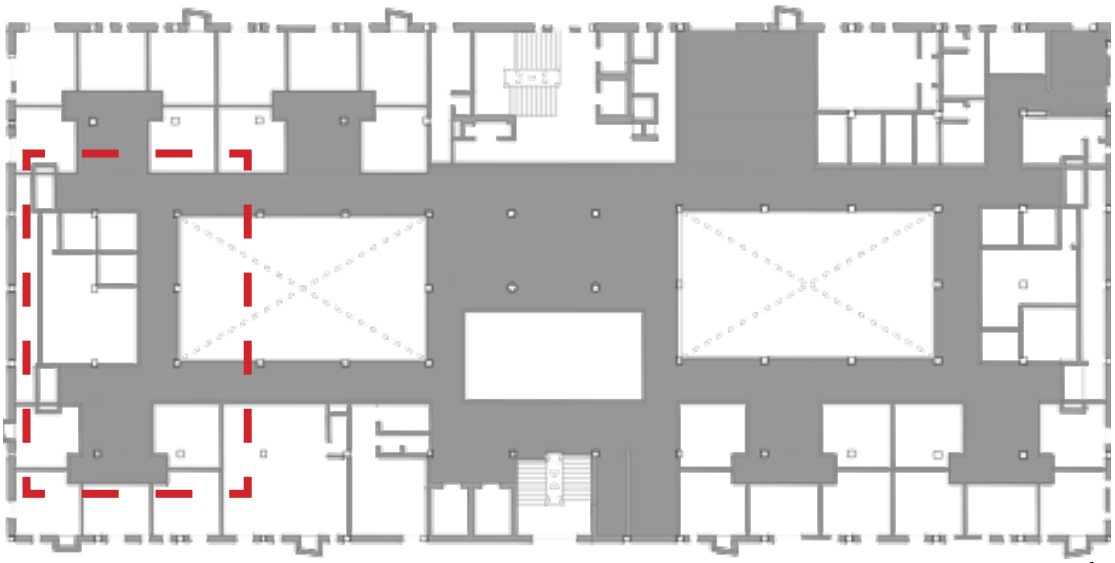

Fig 43: Floor plan of CIMS

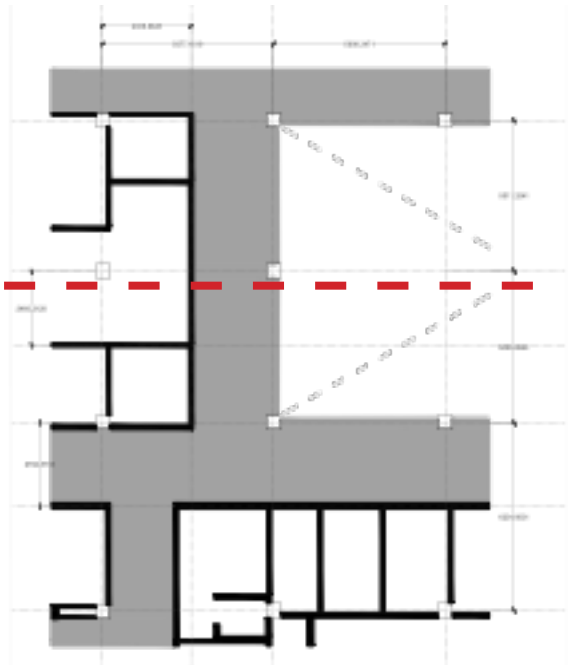

Fig 44: Part plan of East block

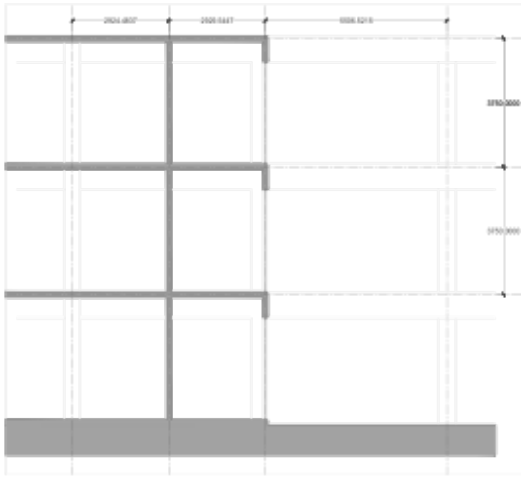

Fig 45: Part section

- The block is oriented in East- West direction.
- The main entry of this block is from East.
- The cabins are arranged at the boundary.
- Due to this the corridor/lobby remains lighted during the day.

- South direction has OPD area.
- Treatment rooms are in west direction.
- Total Area: 2175.26 sq.m.

Fig 46: Activity Mapping

The PINK marked are the sources of the daylight in the first floor of East block and ARROW's are the light fenestrations. And RED dots show the activity mapping during the day. As we can see in above Fig.46 that majiority spaces are occupied surrounding the courtyards i.e. corridors.

East Block Area Calculations of First floor		
Ground Coverage	Open Area	Built-up Area
2401.73 sqm.	310.04 sqm.	2091.69 sqm.

Table 3

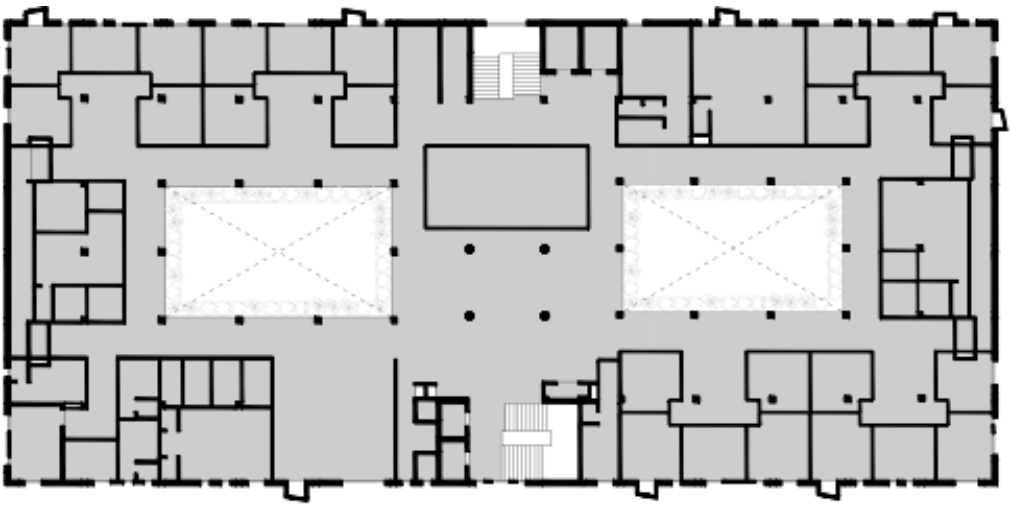

Fig 47: First floor plan

Wall to Window ratio of Facades				
Facade Direction	**North**	**East**	**South**	**West**
Opening Area	7.79 sqm.	29.09 sqm.	7.95 sqm.	33.16 sqm.
Wall area	115.16 sqm.	232.86 sqm.	115.01 sqm.	228.76 sqm.
% Value	6% opening on North facade	11% opening on East facade	6% opening on South facade	13% opening on West facade

Table 4: Wall to window ratio

Daylight Meseaurements

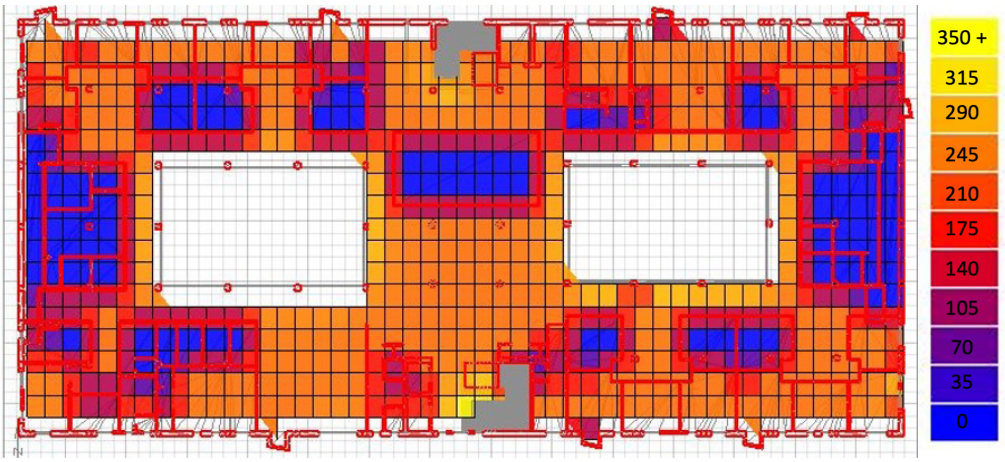

Fig 48: Illuminance of first floor with Grid

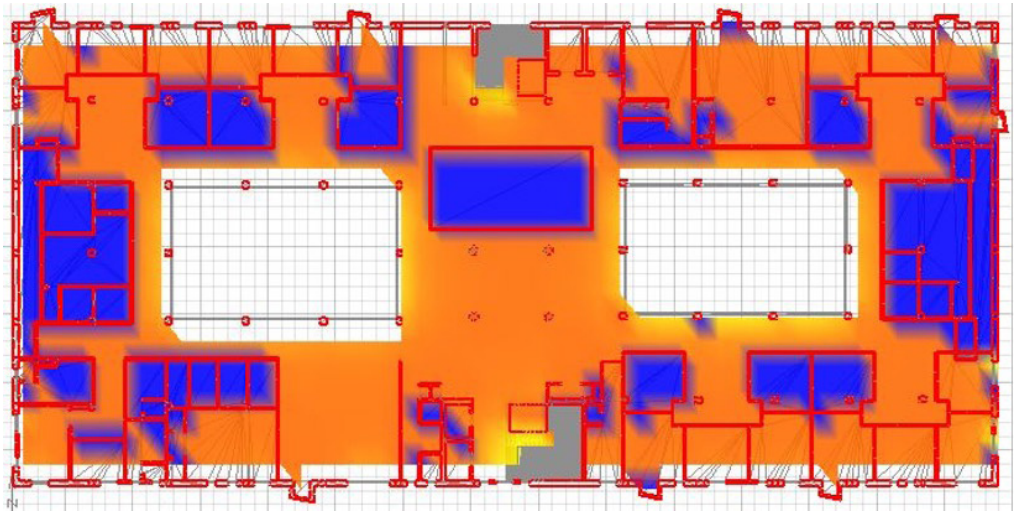

Fig 49: Illuminance of first floor

The corridor/ circulation space is more lighted than the other spaces. The light effect of courtyards is more than the windows in this case study.

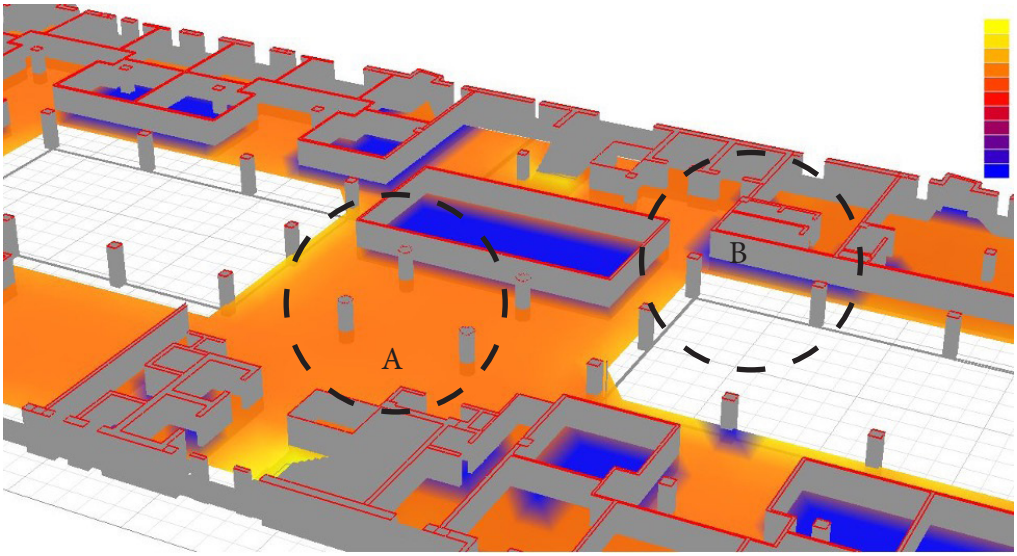

Fig 50: Perspective of Daylight factor

Fig 51: A

Fig 52: B

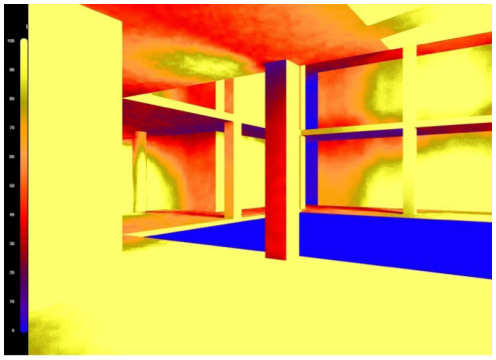

Fig 53 Daylight Simulation of corridors

Fig 54 Picture of the corridor

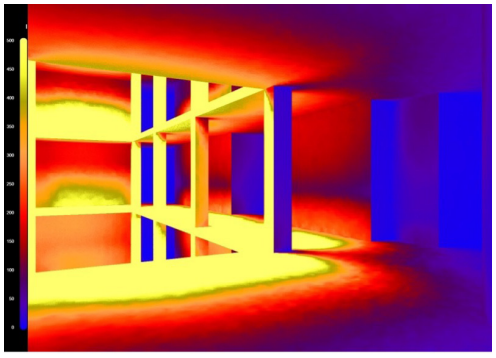

Fig 55 Daylight Simulation of corridor viewing towards courtyard

Fig 56 Picture of central court

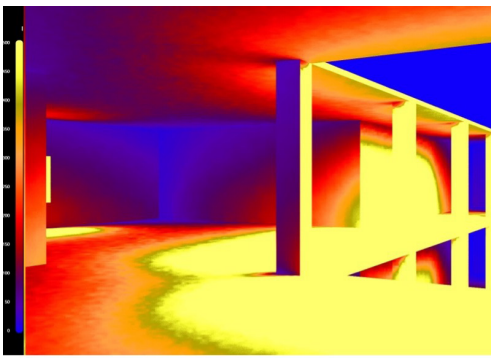

Fig 57 Daylight simulation of corridor

Fig 58 Picture of cabins in corridor

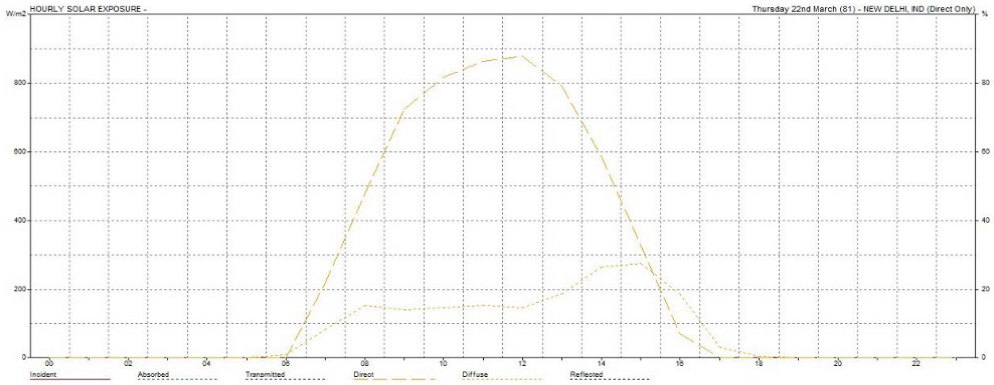

Fig 59 Graph showing hourly sun exposure

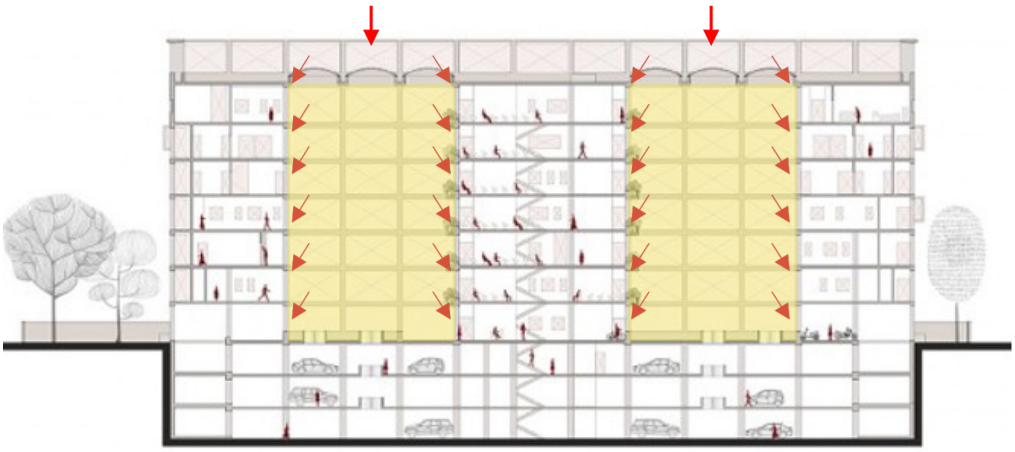

Fig 60 Section of CIMS showing where the light enters into the building

The shaders have been used to get indirect sunlight and to prevent water from coming inside.

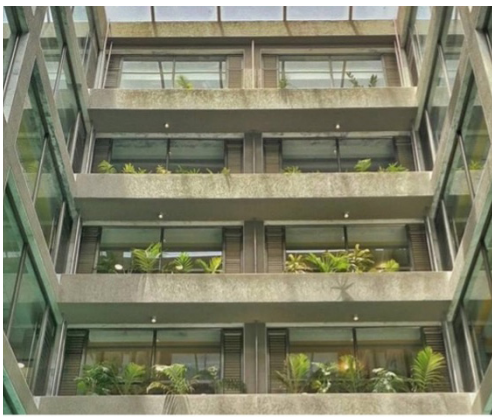

Fig 61 Central courtyard

Fig 62 Waiting seatings in corridors

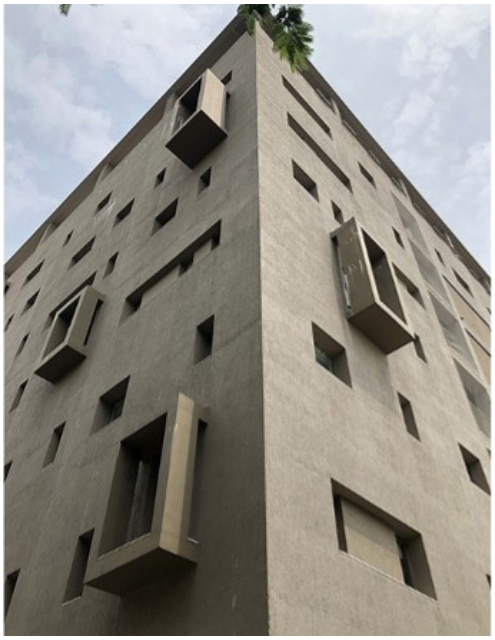

Fig 63 Window variations on facade

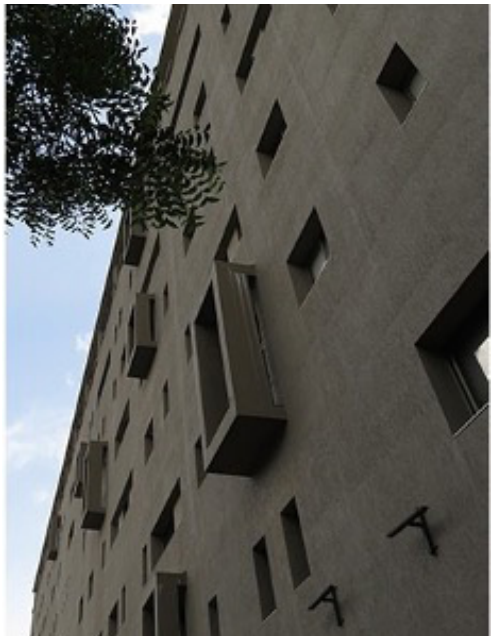

Fig 64 Window variations on facade

Case 2: Shri Dharamsthala Manjunatheshwara Educational Society, Dharwad,
Karnataka

Architects and Designers: Ar. Shirish Beri, Ar. Mahesh Doiphode, Ar. Sikandar Nadaph

Site Area: 2,32,00 sq.m.

Built-up Area: Aprrox. 50,000 sq.m.

Establishment year: 2003

Architectural Style: Modernism

Size: 600 Beds

Fig 65 SDM, Dharwad

- The patients admitted recieve a sense of healthy reassurance and well-being by establishing a very warms, welcome. healthy, green, natural environment with well-lit landscaping arrival atrium courtyard and other functional spaces.
- It balances this atmosphere with proper circulation and placement of diverse fucntional and services.
- This building and its internal spaces does not feel like a hospital, but it works pretty well as a hospital.
- The O.P.Ds area arranged on ground floor and first floor around another well lit and ventilated planted courtyard. The diagnostic departments, pharmacy, kitchen are also on ground floor.

- The administration cabins, doctor cabins, auditorium, wards and sterilization are all located on the first floor. O.T.s are located on the second floor. The patient rooms are in single L- shaped wing with G+6 storeys. Three ICUs are all on 3 different floors.
- This hospital has multiple green pockets where one must pass by them even for the shortest period of time. These green spaces are called courtyards with landscaping, green OTS corners on the bottom of the floor along with the fake grass on every floors.
- The planning is done in such a way where each and every rooms can get access of nature from at least one side.

Fig 66 Satellite image of SDM

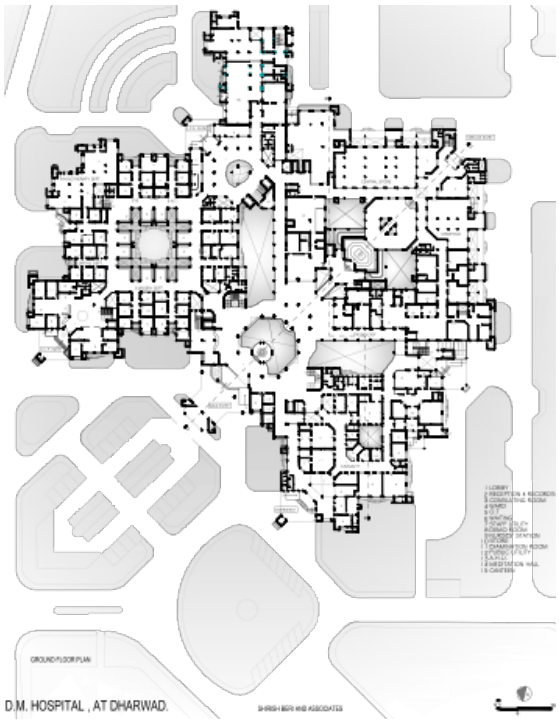

Fig 67 Floor plan of SDM, Dharwad

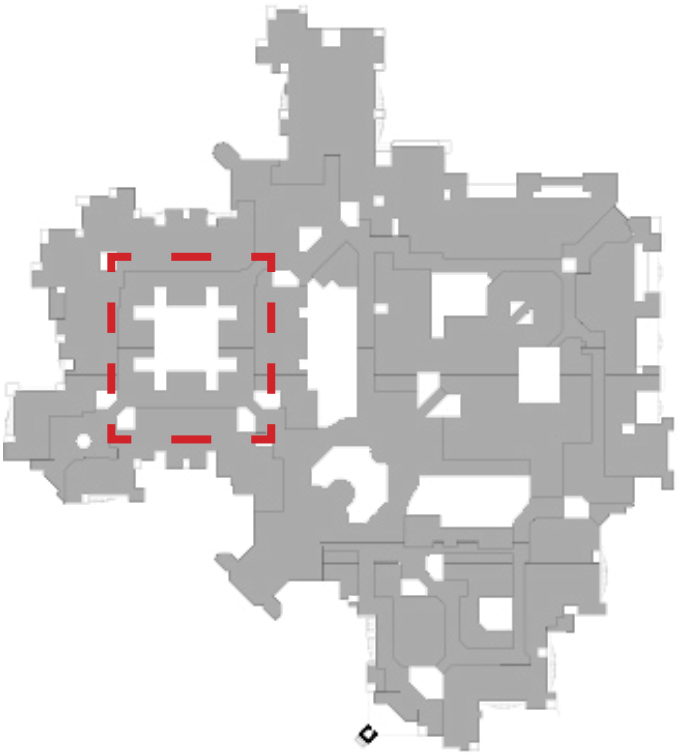

Fig 68 Keyplan built v/s Open

Main building Area Calculations		
Ground Coverage	**Open Area**	**Built- up Area**
22850 sqm	4327.34 sqm	14941.87 sqm

Table 5

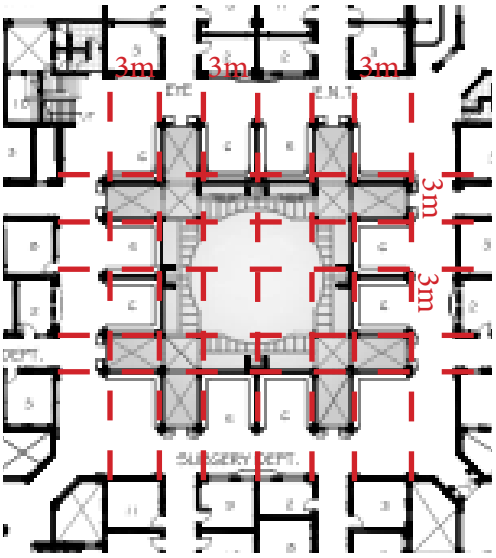

Fig 69 Part plan

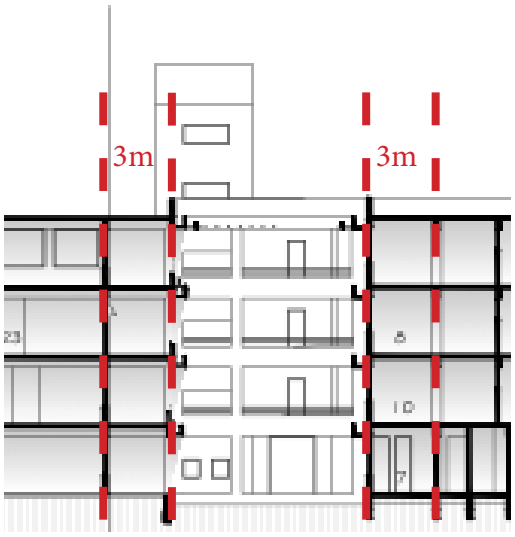

Fig 70 Part section

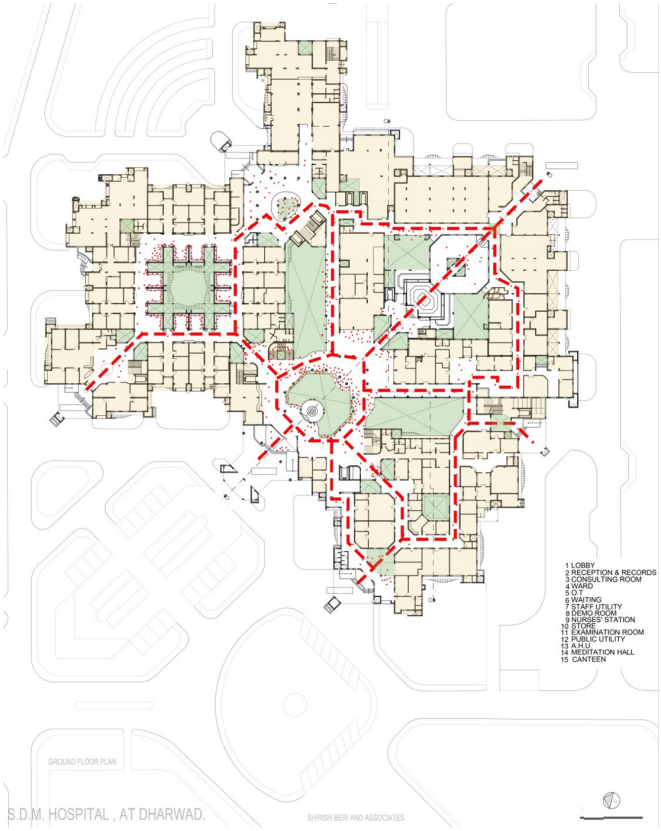

Fig 71 RED dotted line shows the main circulation in this hospital. and RED dots shows the activity mapping

Wall to Window ratio of facade				
Facade direction	**North**	**East**	**South**	**West**
% Value	14% opening on north facade	9% opening on east facade	12% opening on south facade	15% opening on west facade

Table 6

Daylight Measurements

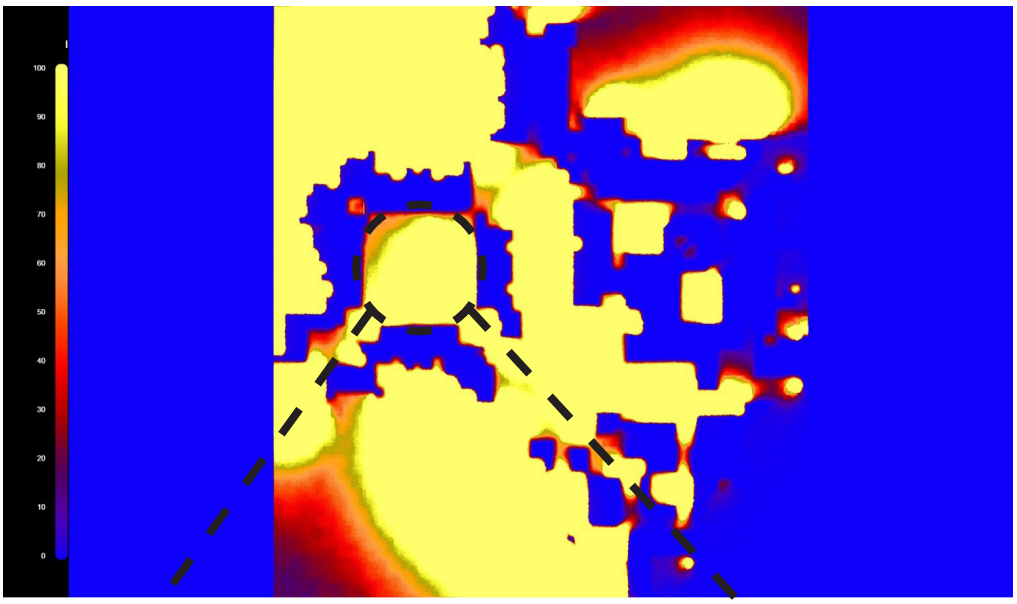

Fig 72 Daylight simulation of single floor

Fig 73 People waiting besides the corridor

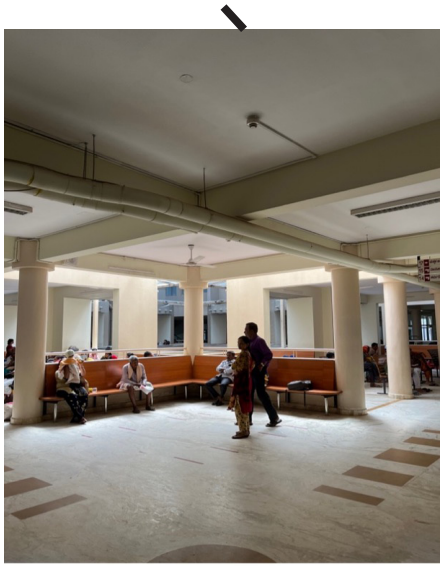

Fig 74 People waiting besides the corridor

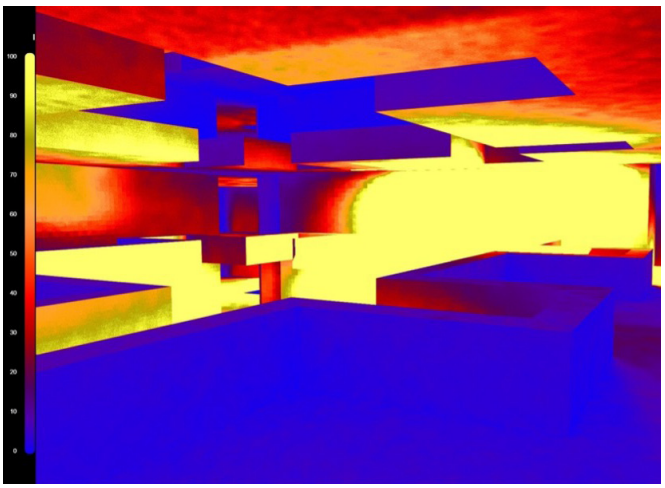

Fig 75 Daylight simulation of corridors

Fig 76 Corridor

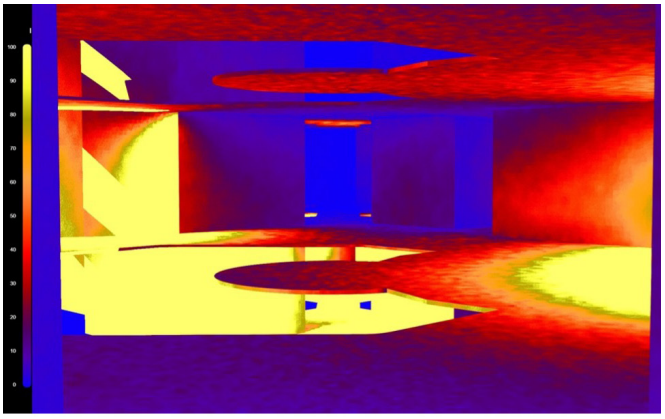

Fig 77 Daylight simulation of corridor connecting courtyard

Fig 78 Corridor with skylight

Fig 79 Variation of windows on facade

Fig 80 Variation of windows on facade

Fig 81 Variation of windows

Fig 82 Courtyard having skylight

Fig 83 Courtyard having waterbody

Fig 84 Corridor connecting court

Fig 85 Lighted corridor

Fig 86 Courtyard with skylights

Case 3: Riviera- Chablais Hospital, Switzerland

Architect: Group-6, GD Architects

Establishment Year: 2019

Floor Area: 60,000 sq.m

Size: 350 beds

- The location of this hospital is near a small village on the border of two swiss regions, is the result of a merger of two regional hospitals.
- It exemplifies how to combine cost effectiveness with the patient welfare: spacious and bedrooms, light filled halls, and landscaped courtyards offer both a pleasant working environment.
- It is built on three levels, the structure blends into the terrain horizontally. It is sized in porportion to both the surrounding landscape and the adjoining community, nestled in the valley.
- It respects the environment by standing straight on the ground, with no basement level.
- The top levels, which holds the lodging area, is composed of dark facade.
- The patient rooms open out onto internal courtyards, shielded from the noise of the highways.
- The atmosphere is protective , it inspires traquility. It is also called as healing environment.
- The first two levels accomodate emergency, imaging, ICU, surgery room, and OPD, etc.

- The glass facade connects these two floors through an interplay of reflection and transparency, conveying the intensity.
- On west side, a single large opening form the entrance to the hsopital.
- The readability is supported by an effective distribution of access flows and the quality of the surroundings. Flows are dived into 3 zones: Products in north, visitors and out patients in west and logistics in east.
- The site's western facade and welcome spaces are clearly visible, leading into an esplanade that goes between calm terrace and a planted meadows spaces with a water pond.
- This hospital is the first hospital in switerzland to have removed all curtains.
- The opaque glass has been used in the facade to maintain the privacy.
- In addition to horizontal layers superposition, the Riviera-Chablais hospital incorporated three frames to allow interior adjustments and extensions.

A medical frame: It is arranges in such a way the medical terminals on the north- south backbone.

A technical frame: It is located on roof, based on network made up on backbone and perpendicular galleries, to allow for easy maintenance and development of the hospital on its own.

A safety frame: With a balanced distribution of fire escapes throughout the unit, to allow for the future scalability.

Fig 87 Entrance of Hospital

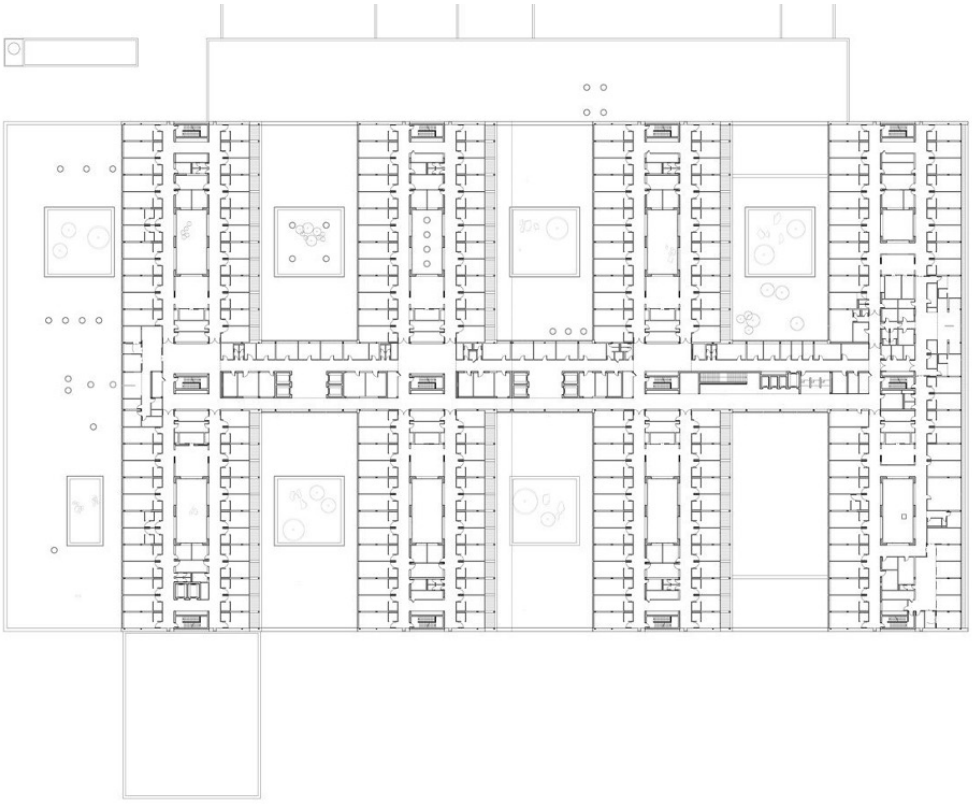

Fig 88 Floor plan of Hospital

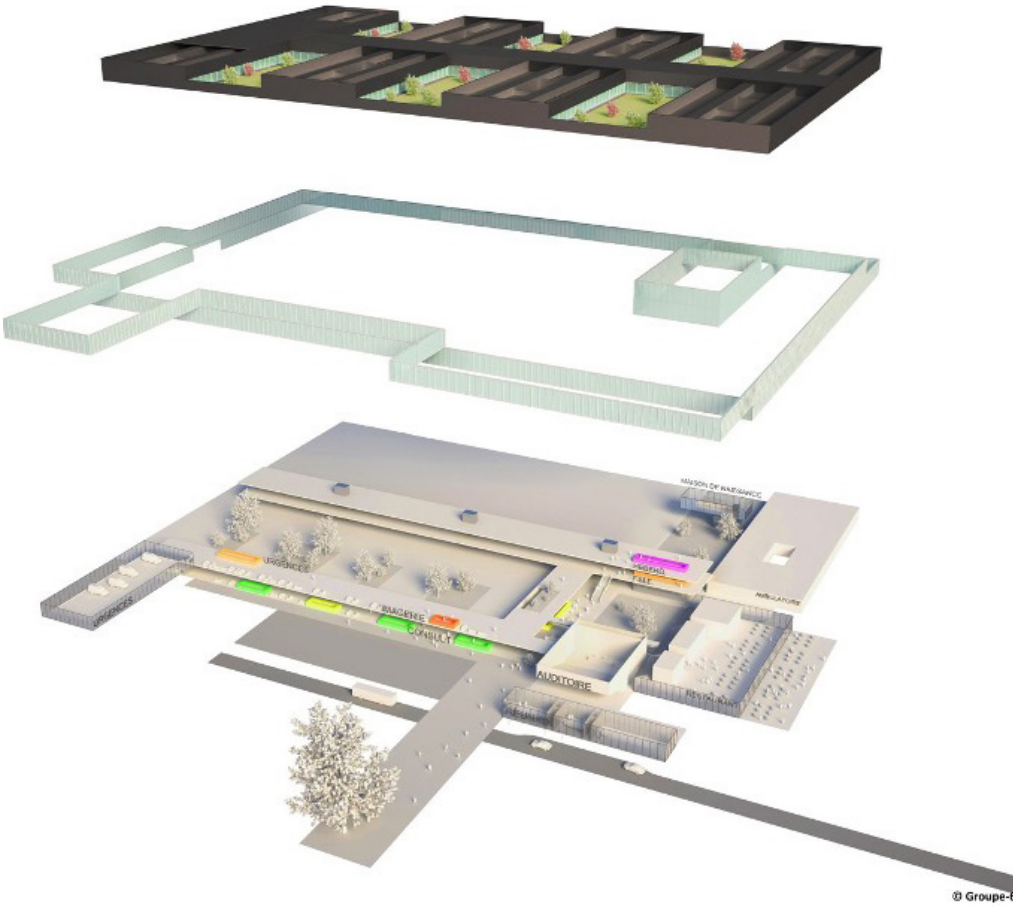

Fig 89 Axometric view of the hospital

Fig 90 Waiting area of hospital

Fig 91 Ward having large windows

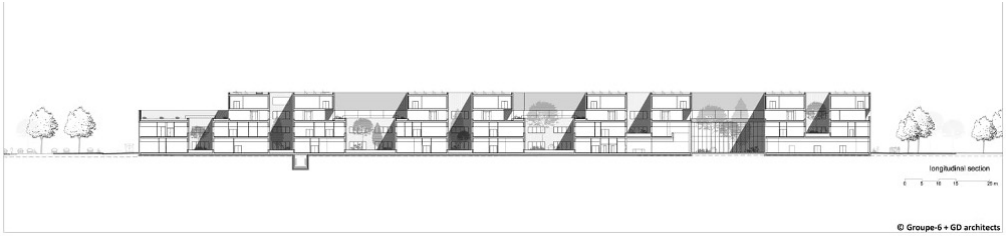

Fig 92 Section of Hospital

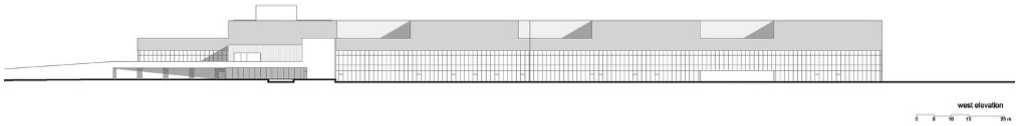

Fig 93 North Elevation

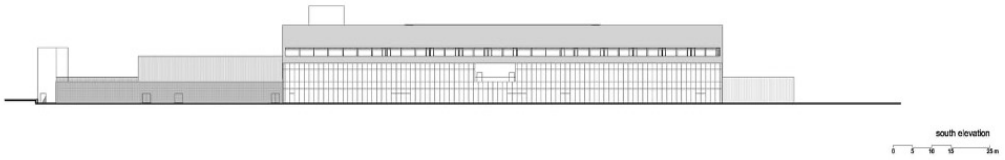

Fig 94 East Elevation

Fig 95

CHAPTER 5
RESULTS

5.1 Synthesis Grid
5.2 Inferences
5.3 Conclusion

Chapter 5: RESULTS

5.1 Synthesis Grid

Comparison of government standards and 2 different designs			
Sr no.	Government Standards (ASHRAE, ISHRAE, NBC, BIS)	CIMS Hospital, Ahmedabad	S.D.M Hospital, Dharwad
1	Corridors- Minimum 150 Lux	Daylight in corridors is > 245. Hence, it proves that this design is designed accoring to the government standards.	Daylight factor in corridors is > 80. Corridors are well lighted but does not need artificial light during the day. But some of the corridors does need artifical light during the daytime . Hence, it proves that at some area the standards are followed.
2	Wards- Min 150 Lux	-	-
3	Service rooms - Min 200 Lux	-	-
4	Incorporated courtyards	Yes	Yes
5	Variation in windows	Yes	Yes

5.2 Inferences

Hospital architecture designs may be optimized to maximize the benfits of natural light.

- **Orientation and layout:** To maximize exposure to natural light, hospital buildings can be constructed with careful considerations in them. This includes placing patient rooms, common spaces, treatment locations in regions where those spaces recieve maximum amount of daylight throughout the day.
- **Light diffusion and Glare reduction:** It is critical to manage the intensity of natural light while maximizing it. Translucent glass, light diffusers and shading devices can be used only where the spaces get hard sunlight.
- **Atriums and courtyards:** These spaces in hospital architecture are the main focus areas of the whole site. Glass roofs or skylights may be used to create well- lit rooms that also promotes the healing and relaxation.
- The areas like OT, ICU which are dark areas can be separated as they don’t require much natural light. These spaces can be separated floor wise.

5.3 Conclusion

- The current living standard in this case study has been matched with the required lighting levels by government regulations in the public areas of hospitals, according to the major results gained from this study.
- According, to the data and photographs, people prefer to sit for long periods of time in rooms within ample natural light or wide windows for views over gloomy artificial lighted locations. This is revealed in this research people's psychology has been affected due to influence of daylight.
- As a result, architects or designer's should evaluate the key aspects of various regulatory guidelines on daylighting in public locations.

List of Figures

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