

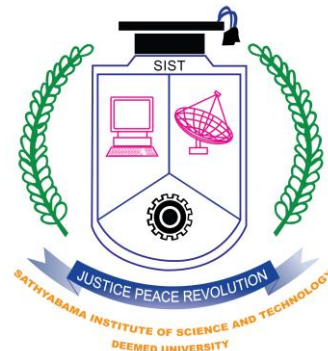
OPTIMISATION OF DAYLIGHTING-PROPOSAL FOR KALAINAR MEMORIAL LIBRARY

A Thesis

Submitted in partial fulfillment of the requirements for the award of
Master of Architecture degree in Sustainable Architecture

by

G.MUKUNTH (40890010)



**DEPARTMENT OF ARCHITECTURE
SCHOOL OF BUILDING AND ENVIRONMENT**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A" by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119

MAY 2022



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DEPARTMENT OF ARCHITECTURE

BONAFIDE CERTIFICATE

This is to certify that this Report is the bonafide work of **G.MUKUNTH (40890010)** who carried out the Thesis entitled "**OPTIMISATION OF DAYLIGHTING-PROPOSAL FOR KALAI GNAR MEMORIAL LIBRARY**" under our supervision from January 2022 to May 2022.

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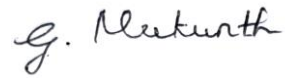
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DECLARATION

I **MUKUNTH.G** hereby declare that the Thesis Report entitled “**OPTIMISATION OF DAYLIGHTING-PROPOSAL FOR KALAIgnAR MEMORIAL LIBRARY**” is done by me under the guidance of **AR.SHEETAL AMRAOTKAR** (Internal) and **AR.KRITHIKHA MUTHUKRISHNAN** (External) at Sathyabama Institute of Science and Technology is submitted in partial fulfillment of the requirements for the award of Master of Architecture degree in Sustainable Architecture

DATE: 6.5.2022

PLACE: Chennai



SIGNATURE OF THE CANDIDATE

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ABSTRACT

Public libraries have the ability to function as a vibrant community hub, offering social, cultural and educational resources. The city of Madurai lacks adequate public libraries to meet the demands of budding minds. Students, research scholars and those preparing for competitive tests would benefit much from the project. Literature review is done on daylight integration strategies, standards and green building rating system prescriptive requirements. Live case study of Anna Centenary library is done to understand the spatial planning and daylight strategies. The case study is analyzed using quantitative and qualitative analysis. The site is studied in live and the area programme was prepared. It is followed by climate study and detailed site analysis. Site zoning is done comparing three iterations. The design development focuses on building orientation, fenestration design, atrium design, geometry of shading device and glazing materials. The detailed design of the library is done incorporating the sustainable design features. The conclusion is arrived by performing a analysis of daylight performance of each reading space. It is proved that all the reading spaces achieve the standard level of lux and is free from glare. The daylight metrics values are compared with the prerequisites of the Green rating systems and ECBC Compliance check is also done.

TABLE OF CONTENTS

CHAPTER No.	TITLE	PAGE No.
	ABSTRACT	v
	LIST OF TABLES	x
	LIST OF FIGURES	xii
1	INTRODUCTION	1
1.1	AIM	1
1.2	RESEARCH QUESTIONS	1
1.3	OBJECTIVE	1
1.4	NEED FOR THE STUDY	1
1.5	LIMITATIONS FOR THE STUDY	1
1.6	METHODOLOGY	2
2	LITERATURE REVIEW	3
2.1	VERTICAL WINDOWS	3
2.2	TOP LIGHTING STRATEGIES	4
2.3	SKYLIGHT DESIGN	6
2.4	DCR REGULATION FOR ASSEMBLY BUILDINGS	6
2.5	LIBRARY STANDARDS	7
2.6	SPATIAL STANDARDS	9
2.7	DESIGN GUIDELINES	10

2.8	GREEN RATING SYSTEM-PERSPECTIVE REQUIREMENTS	11
2.8.1	LEED Daylight requirements	11
2.8.2	SP 41 Standards	11
2.8.3	GRIHA-Daylight	12
2.9	ECBC DAYLIGHT STANDARDS	13
2.10	NBC 2016 ILLUMINATION LEVELS	13
3	CASE STUDY	14
3.1	LIVE CASE STUDY: ANNA CENTENARY LIBRARY	14
3.1.1	Sustainable Features	14
3.1.2	Zoning Analysis	14
3.1.3	Access Road	14
3.1.4	Spatial Zoning	15
3.1.5	Zoning Analysis	16
3.2	CASE STUDY 2- LIBRARY AND CULTURAL CENTRE- FRITZ HANSEN FACTORY-DENMARK	17
3.4	CASE STUDY 3- BISHAN PUBLIC LIBRARY	18
3.5	CASE STUDY 4- LILAVATHI LALBHAI LIBRARY	19
4	SITE ANALYSIS	20
4.1	SUN PATH AND WIND DIRECTION	20
4.2	SITE APPROACH	20
4.3	BUILDING TYPOLOGY AND LANDUSE	21
4.4	CONTOUR AND VEGETATION	21

4.5	SHADOW ANALYSIS	22
4.6	RADIATION ANALYSIS	22
4.7	DESIGN STRATEGIES	22
4.8	WIND ANALYSIS	23
4.9	AREA STATEMENT	24
5	DESIGN DEVELOPEMENT	25
5.1	ZONING	25
5.1.1	Comparitive Analysis	28
5.2	BLOCK ORIENTATION ANALYSIS	28
5.3	FORM FACTOR ANALYSIS	29
5.3.1	Design Recommendation	29
5.3.2	Methodology	29
5.4	OPTIMISATION OF FLOOR PLATE DEPTH	31
5.4.1	Daylighting Metrics For Green Rating	31
5.4.2	Methodology	31
5.4.3	Assumptions	32
5.5	SHADOW ANALYSIS	34
5.6	ATRIUM GEOMETRY OPTIMISATION	35
6	DETAILED DESIGN	36
6.1	SITE PLAN	36
6.2	SUSTAINABLE FEATURES	36
6.3	FLOOR PLANS	37
6.4	DESIGN OF SHADING DEVICES	44
6.5	DESIGN OF SHADING ELEMENTS	47

6.5.1	Jaali-Design Iterations	48
6.6	DAYLIGHT ANALYSIS	51
6.7	CONCLUSION	56
REFERENCES		57

LIST OF TABLES

TABLE No.	TITLE	PAGE No.
2.1	Toilet Standards	7
2.2	Library Standard Guide lines	8
2.3	Library Space Requirements	8
2.4	Simulation of spatial daylight autonomy	11
2.5	Simulation of Illuminance	11
2.6	SP 41 lux Standards	11
2.7	GRIHA-Daylight Requirements	12
2.8	ECBC Daylight Standards	13
2.9	NBC Lux Requirements	13
4.1	Wind Data	20
4.2	Area Statement	24
5.1	Zoning-Comparitive Analysis	28
5.2	Block Orientation Analysis	28
5.3	Form Factor Analysis Comparison	29
5.4	Form Factor Analysis Comparison	30
5.5	Optimisation of Floor Pate Depth Step 1	32
5.6	Optimisation of Floor Pate Depth Step 2	32
5.7	Optimisation of Floor Pate Depth Step 3	33
5.8	Shadow Analysis-Iteration Comparison	34
5.9	Atrium Geometry Optimisation	35
6.1	Jali Block Iterations	48

6.2	Jali Screen for West Wall	49
6.3	Jali Screen for East Wall	49
6.4	Materials Study	50
6.5	Water Fixures	50
6.6	Materials Comparison Table	51
6.7	Daylight Analysis-Ground Floor	51
6.8	Daylight Analysis-Ground Floor-2	52
6.9	Daylight Analysis-First Floor	52
6.10	Daylight Analysis-Second Floor	52
6.11	Daylight Analysis-Third Floor	53
6.12	Daylight Analysis-Fourth Floor	53
6.13	Daylight Analysis-Fifth Floor	53
6.14	Daylight Analysis-Sixth Floor	54
6.15	Comparitive Analysis-1	54
6.16	Comparitive Analysis-2	55
6.17	Comparitive Analysis-3	55

LIST OF FIGURES

FIGURE No.	TITLE	PAGE No.
2.1.	Cross section showing light distribution from a Single sided window installation	3
2.2	Effect of Window height on DF	3
2.3	Variation of DF across a room using two types of windows, both having the same total area	4
2.4	Use of louvers for diffused light	4
2.5	Use of sun catcher	5
2.6	North lighting	5
2.7	Reflective surfaces	5
2.8	Sun catcher design	5
2.9	Design of skylight	6
2.10	Skylight	6
2.11	Light distribution	6
2.12	Stack Room Guidelines	9
2.13	Reading Room Standards	10
3.1	OAT above Assembly	14
3.2	Exterior View	14
3.3	Spatial Zoning	15
3.4	Space Planning	16

3.5	Interior Views	16
3.6	Library and cultural center	17
3.7	Ground floor plan-Library and cultural center	17
3.8	Bishan Public library	18
3.9	Ground floor plan-Bishan Public library	18
3.10	Lilavathi lalbhai library	19
3.11	Ground floor plan-Lilavathi lalbhai library	19
4.1	Sun path and Wind direction	20
4.2	Site Approach	20
4.3	Building typology and landuse	21
4.4	Contour and vegetation	21
4.5	Shadow Analysis	22
4.6	Radiation Analysis	22
4.7	Design Strategies	22
4.8	Figure Ground Map	23
4.9	Wind analysis	23
5.1	Iteration 3	25
5.2	Iteration 2	26
5.3	Iteration 1	27
5.4	Form factor analysis comparison	29
5.5	Design Ideas	30
5.6	Design strategies	31

5.7	Conceptual Section	33
6.1	Site Plan	36
6.2	Sustainable features	36
6.3	Ground floor plan	37
6.4	First floor plan	38
6.5	Second floor plan	39
6.6	Third floor plan	40
6.7	Fourth floor plan	41
6.8	Fifth floor plan	42
6.9	Sixth floor plan	43
6.10	View of South façade	44
6.11	View of North façade	45
6.13	South-east View	47
6.14	Jali block Iterations	48
6.15	Awning design	48

LIST OF SYMBOLS AND ABBREVIATIONS

LEED	-	Leadership in Energy and Environmental design
IGBC	-	Indian green building council
GRIHA	-	Green rating for integrated habitat assessment
UDI	-	Useful daylight illuminance
DA	-	Daylight Autonomy
sDA	-	Spatial daylight autonomy
DF	-	Daylight factor
ASE	-	Annual solar exposure

CHAPTER 1

INTRODUCTION

1.1 AIM

The aim of the study is to design a multi-storey public library in Madurai with optimised daylight integration.

1.2 RESEARCH QUESTIONS

1. How to create glare-free indoor environment with minimal solar exposure ?
2. How atriums can act as light wells and a social interaction zone ?
3. How efficient are active daylight systems in illuminating the spaces ?

1.3 OBJECTIVES

1. To create a public library that goes beyond the conventions and includes spaces that foster creativity.
2. To create engaging spaces that evokes a sense of connectivity and promotes interaction.
3. To optimise the day lighting in the Library and focus on user's visual comfort.
4. To determine the optimum floor plate depth and introduce Atrium and courts in the design.

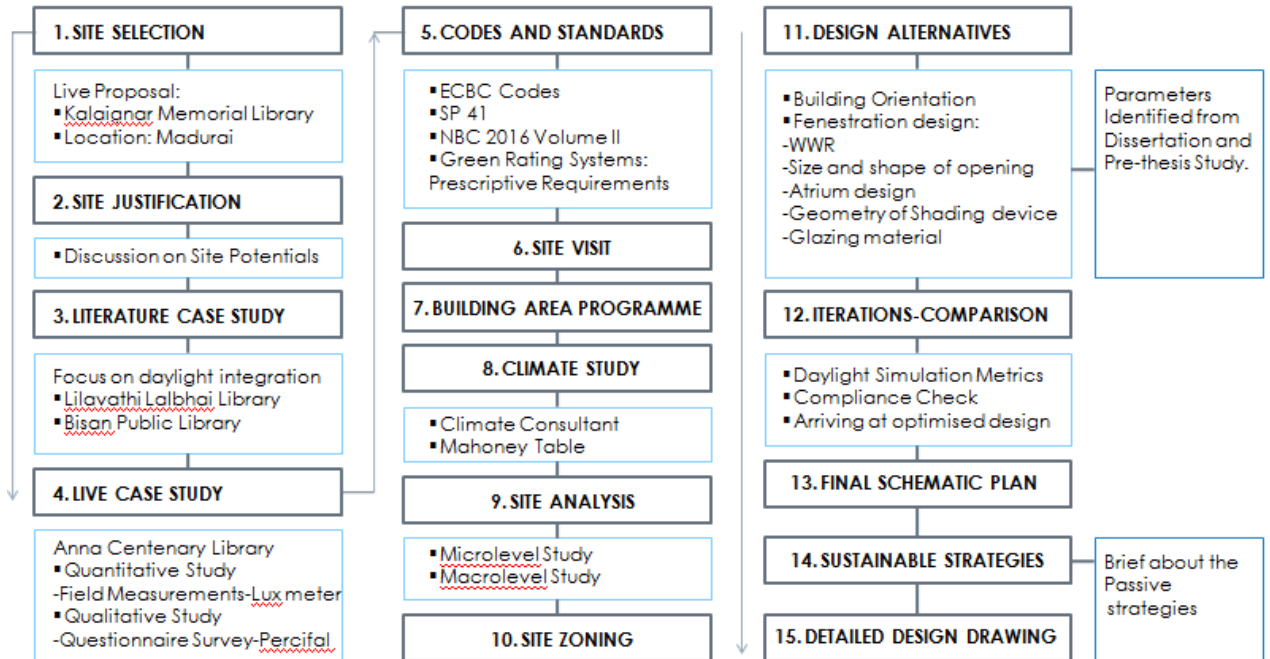
1.4 NEED FOR THE STUDY

People nowadays have easy access to the internet, which acts as a source of knowledge. Books are no longer the only source of information, and libraries are no longer the only place to learn. In Tamil Nadu, public libraries are seen as a repository of books that fail to stir public interest. Due to insufficient lighting and poor maintenance most libraries fail to provide a conducive learning environment to the readers. This creates a need for a Public library with proper daylight integration.

1.5 LIMITATION

1. The study focuses on daylight integration in a Library pertained to Warm and humid climatic zone.
2. Energy performance, Water performance and Waste management are not covered in detail under the study.

1.6 METHODOLOGY



CHAPTER 2

LITERATURE REVIEW

2.1 VERTICAL WINDOWS

Useful daylight will reach only a distance of 2.5 times the height of the top of the window above the workplane.

In a standard office building with a window with a window height of 2.5 m, this means a maximum of about 5-7 metres.

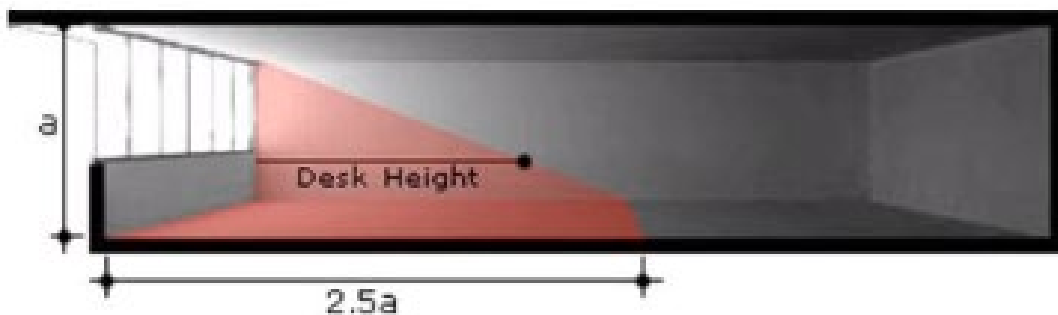


Fig 2.1 *Cross section showing light distribution from a Single sided window installation*

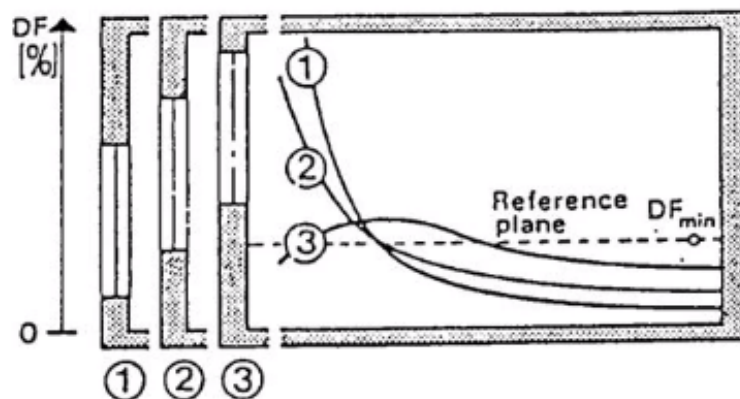


Fig 2.2 *Effect of Window height on DF*

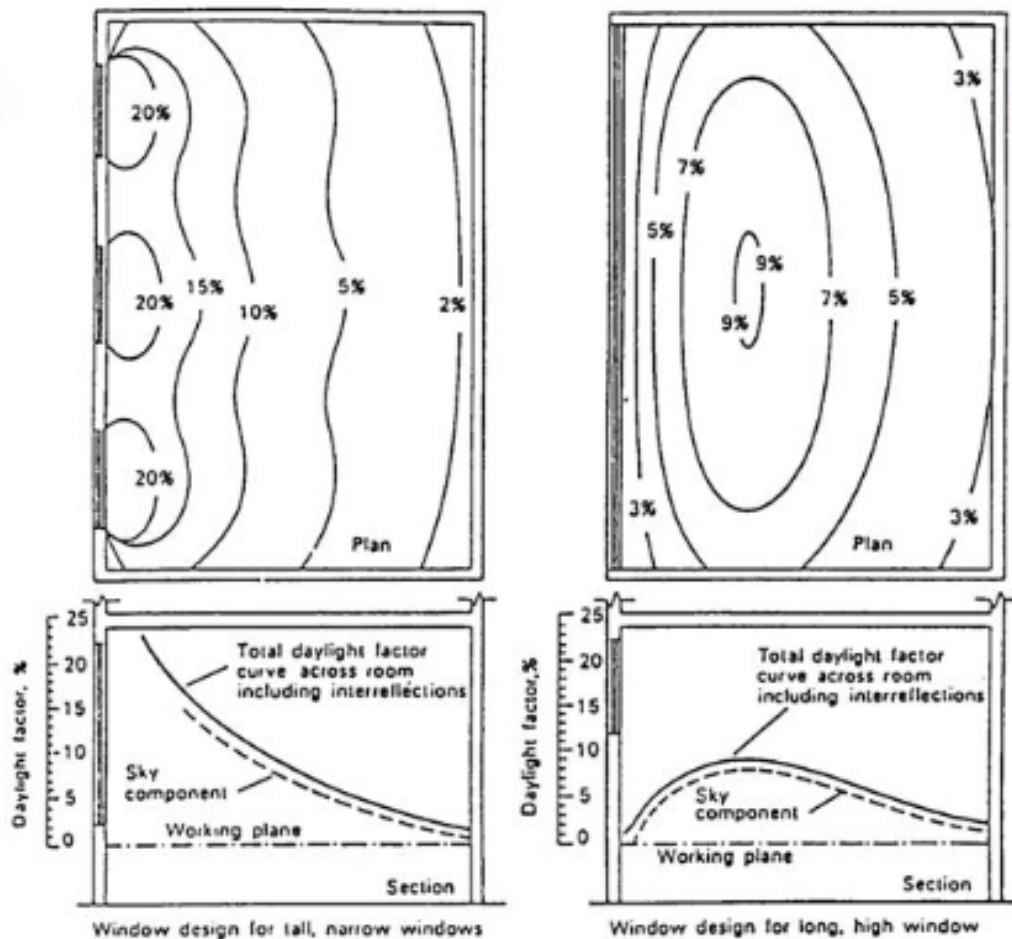


Fig 2.3 Variation of DF across a room using two types of windows, both having the same total area

The advantage of Window A is that it offers good open view whereas Window B would provide more even daylight illumination.

2.2 TOPLIGHTING STRATEGIES

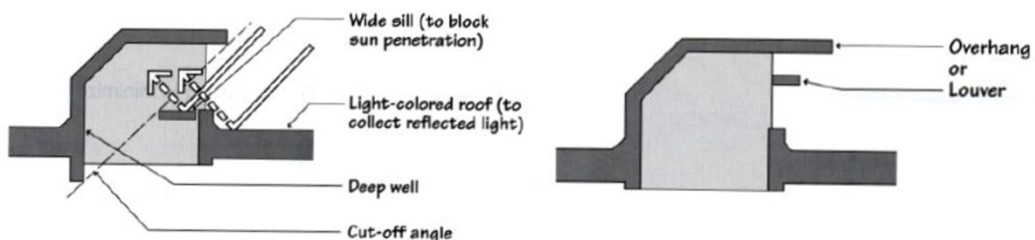


Fig 2.4 Use of louvers for diffused light

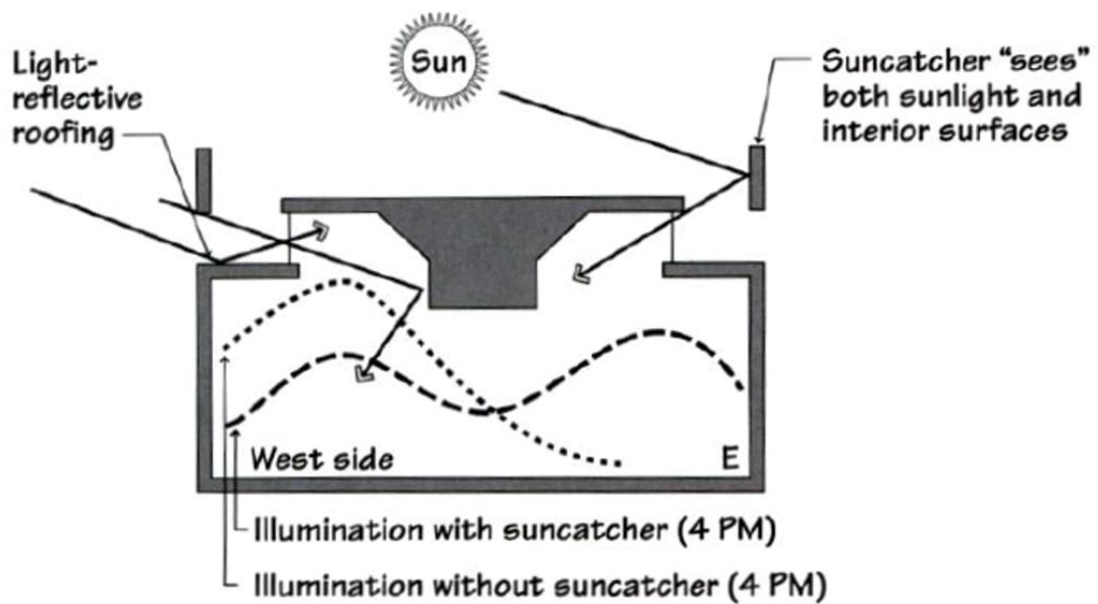


Fig 2.5 Use of sun catcher

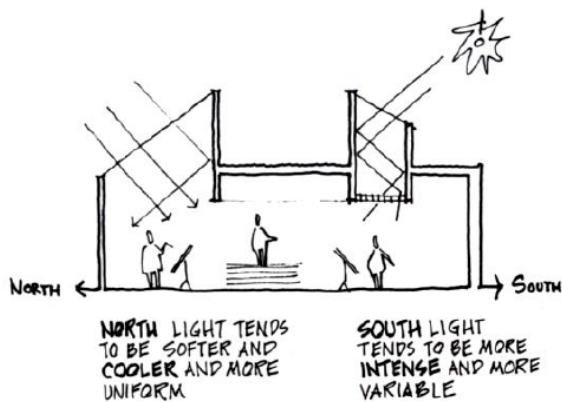


Fig 2.6 North lighting

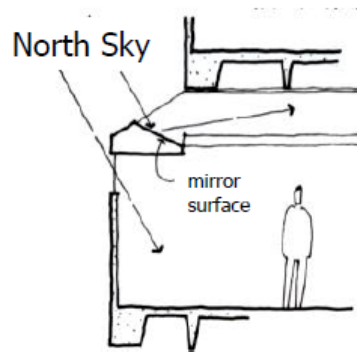


Fig 2.7 Reflective Surface

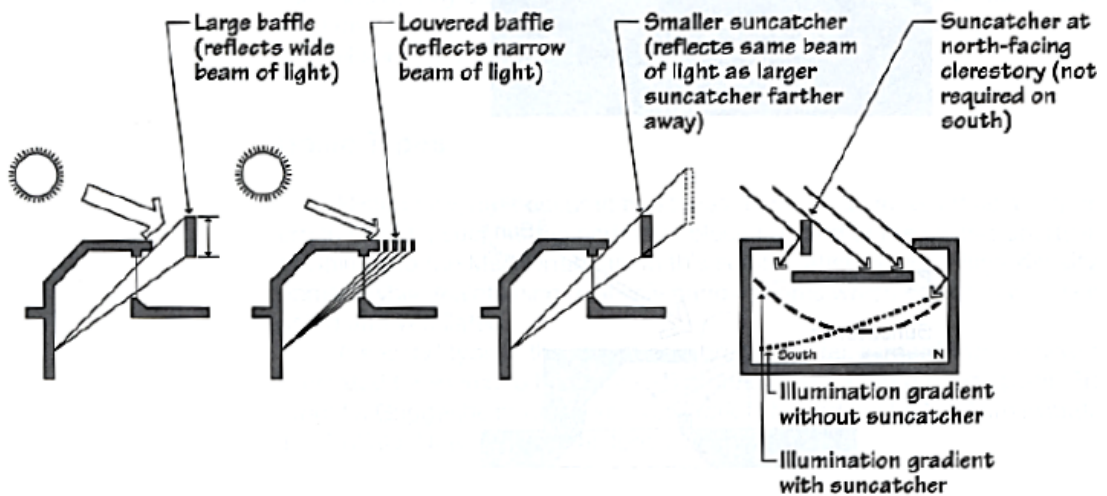


Fig 2.8 Sun catcher Design

2.3 SKYLIGHT DESIGN

A skylight system is considered as the most basic top lighting strategy. It is usually designed as horizontal or slanted roof opening to capture daylight.

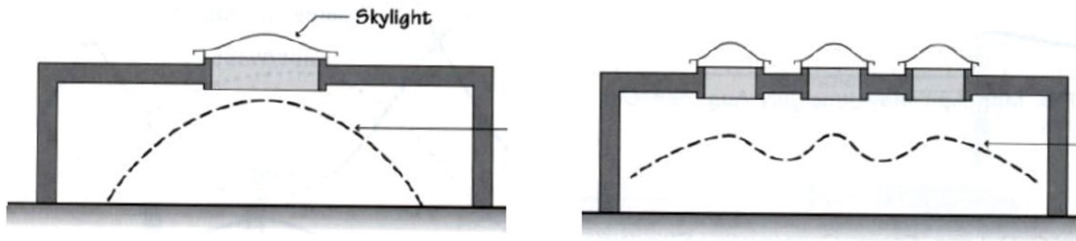


Fig 2.9 Design of skylight

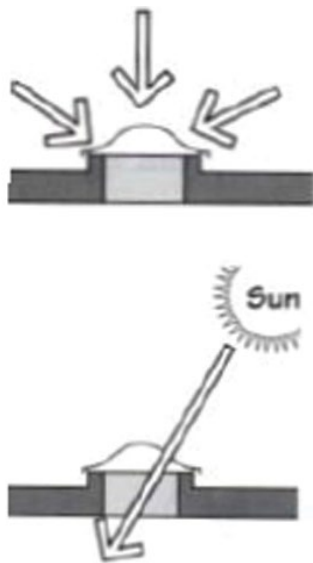


Fig 2.10 Skylight

Overcast Sky: Horizontal skylights collect more light. *High sun Angle:* Horizontal skylight receives maximum heat gain.

Skylight shapes can help keep the heat out during the hottest part of the day, but still allow plenty of daylight.

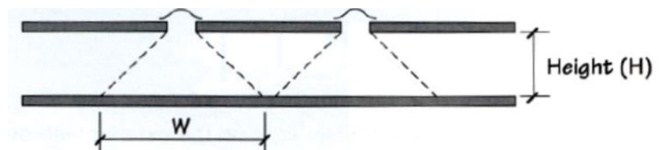


Fig 2.11 Light distribution

2.4 DCR REGULATION FOR ASSEMBLY BUILDINGS

Minimum width of the access road is 18m.

The maximum FSI is 3.25.

The maximum ground coverage is 50%.

Minimum set back all around is 7m.

Minimum spacing between the blocks is 7m.

Minimum width of the vehicular passage is 7.2m.

The minimum width of corridor and veranda is 2m.

The minimum width of the access path is 1.8m.

Minimum width of the parking bay is 3.6m.

Minimum width of the Ramp is 1.8m.

The slope of the ramp should be 1:12.

The minimum size of the toilet is 1.5m x 1.75 m.

The minimum width of the staircase is 2m.

1 car space and 1 two wheeler space for every 50 sq.m area.

Table 2.1 Toilet Standards

Sl. No.	Sanitary Unit	For Public		For Staff	
		Male	Female	Male	Female
1.	Water Closet (W.C.)	One for 200 persons upto 400 persons. For over 200 persons, add at the rate of 1 per 250 persons or part thereof	One per 100 persons upto 200 persons. For over 200 persons, add at the rate of 1 per 150 persons or part thereof	One for 1-15 persons. Two for 16-35 persons	One for 1-12 persons. Two for 13-25 persons, add at the rate of 1 per 6 persons or part thereof
2.	Ablution Taps	One in each W.C.	One in each W.C.	One in each W.C	One in each W.C
3.	Urinals	One for 50 persons or part thereof	--	Nil upto persons One for 7-20 persons Two for 21-45 persons	--
4.	Wash Basins	One for every 200 persons or part thereof. For over 400 persons, add at the rate of 1 per 250 persons or part thereof.	One for every 200 persons or part thereof. For over 200 persons, add at the rate of 1 per 150 persons or part thereof	One for 1-15 persons Two for 16-35	One for 1-12 persons Two for 13-25 persons
5.	Cleaner's Sink	One per floor, minimum			
6.	Drinking Water Fountain	One per 100 persons or part thereof			
7.	Shower/ Bath	As per each kitchen			

2.5 LIBRARY STANDARDS

Library plays a vital role in academic and research system and that is why library is considered to be the heart of educational / research system.

Bureau of Indian Standards came out with Indian Standard: 1553-1960 Code of practice relating to primary elements in the design of library building.

Table 2.2 Library Standard Guidelines

S. No.	Type of Library	No. of volumes	No. of periodicals for display	No. of Reader's seats
1	National Central Library	2,00,000 to 6,00,000	500 to 2,000	500 to 2,000
2	State Central Library	1,00,000 to 5,00,000	100 to 1,000	500 to 1,500
3	City Central Library	50,000 to 3,00,000	50 to 1,000	100 to 1,000
4	Rural Central Library	50,000 to 3,00,000	Nil	50
5	Branch Library	50,000 to 25,000	20 to 50	50 to 200

Table 2.3 Library Space Requirements

S. No.	Room	Public Library				
		NCL	SCL	CCL	RCL	BL
1	Stack Room	R	R	R	R	R
2	Catalogue Room	R	R	R	R	R
3	General Reading Room	R	R	R	R	R
4	Periodicals Reading Room	R	R	R	-	-
5	Special Reading Room	R	R	R	-	-
6	Research Cubicles	R	R	R	-	-
7	Group Study Room	R	R	R	-	-
8	Seminar Room	R	R	R	-	-
9	Conference Room	R	R	R	-	-
10	Exhibition Room	R	R	R	R	-
11	Librarian's Room	R	R	R	R	R
12	Deputy Librarian's Room	R	R	R	R	-
13	Technical Staff Room	R	R	R	R	-
14	Administrative Staff Room	R	R	R	R	-
15	Committee Room	R	R	R	R	-
16	Display space at Entrance	R	R	R	R	-
17	Night Watchman's Room	R	R	R	R	R
18	Microfilm Reading Room	R	R	R	-	-
19	Document Reproduction Room	R	R	-	-	-
20	Audio-visual Room	R	R	R	R	-

2.6 SPATIAL STANDARDS

Stack Room Guidelines:

Clear length in metres:

$1.80n + 3.10$, where n is the no .of rows of book racks.

1 sq.m Stack room-150 Volumes.

Centre to centre distance between two consecutive racks is 1.80m.

Distance between end wall and centre of nearest rack is 1.55m

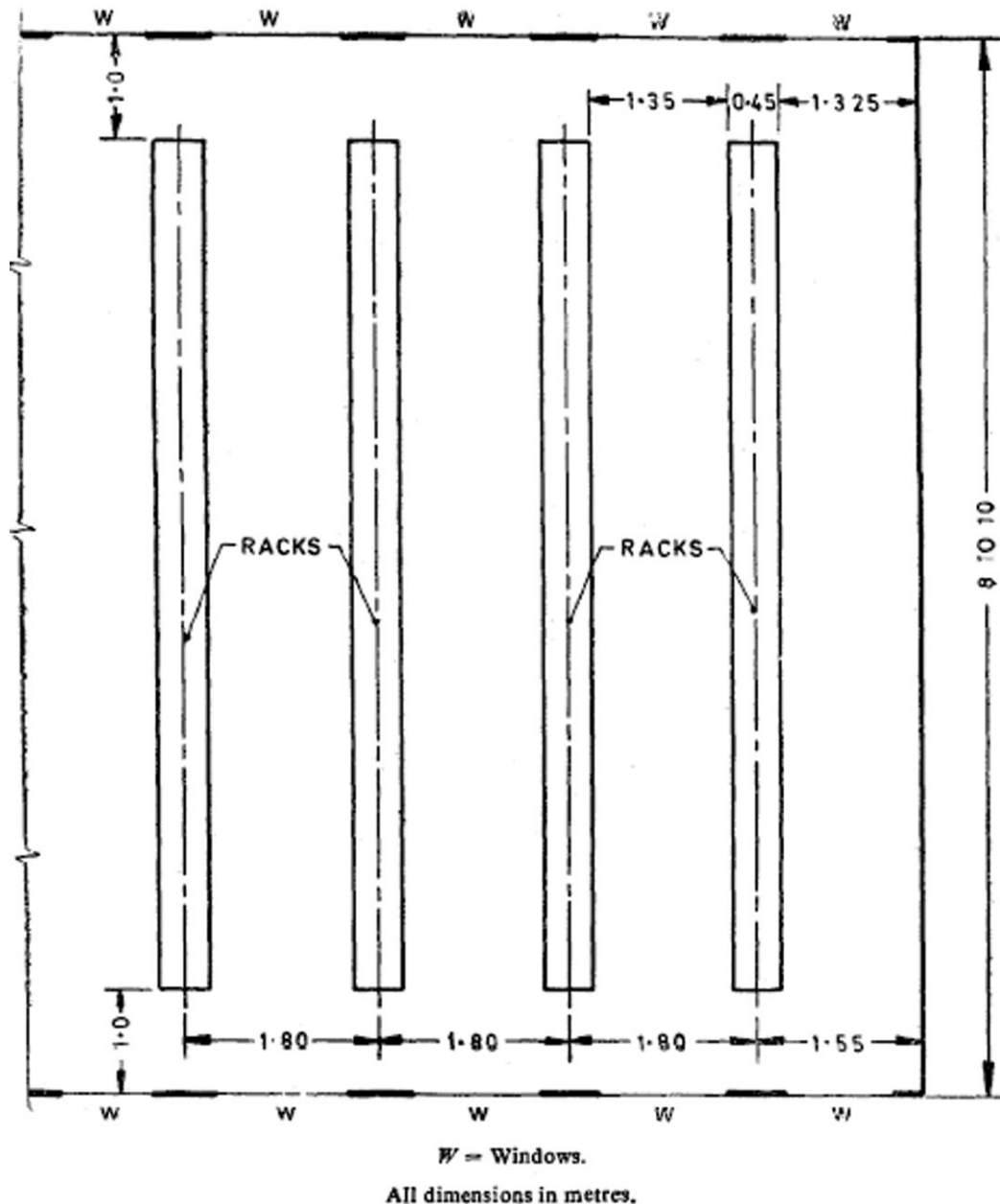


Fig 2.12 Stack Room Guidelines

Floor to ceiling clear height should be atleast 2.4m



Separate open spaces are available to park cars and/or other vehicles. A clear passageway of 6 m width is maintained continuous to and around the building. Adequate passageway (not less than 6 m wide) is required for fire appliances to enter the premises is provided

2.8 GREEN RATING SYSTEM-PRESCRIPTIVE REQUIREMENTS

2.8.1 LEED DAYLIGHT REQUIREMENTS

Table 2.4 Simulation of Spatial daylight autonomy

New Construction, Core and Shell, Schools, Retail, Data Centers, Warehouses & Distribution Centers, CI, Hospitality	
sDA (for regularly occupied floor area)	Points
55%	2
75%	3

Table 2.5 Simulation of Illuminance

New Construction, Core and Shell, Schools, Retail, Data Centers, Warehouses & Distribution Centers, Hospitality, CI	
Percentage of regularly occupied floor area	Points
75%	1
90%	2

Illuminance levels will be between **300 lux and 3,000 lux** for 9 a.m. and 3 p.m., both on a clear-sky day at the equinox, for the floor area indicated.

Option3: Point for Daylight Floor Area (Measurement)

2.8.2 SP 41 STANDARDS

Table 2.6 SP 41 lux Standards

Libraries:

Shelves, stacks	70 to 100 ↑
Reading tables	300

v) Libraries

Stack room	0.9-1.9
Reading room	1.9-3.75
Counter area	2.5-3.75
Catalogue room	1.9-2.5

2.8.3 GRIHA-DAYLIGHT

Table 2.7 GRIHA-Daylight Requirements

Alternative 1
The WWR and SRR to not exceed <u>60% & 5% respectively</u> &; All the fenestrations meet the SHGC requirement of ECBC-2007/Weighted Façade average SHGC (for each orientation) meets <u>SHGC requirements</u> of ECBC-2007 OR; Alternatively use <u>Tables 9 & 10 of SP 41</u> to design the shading device for the windows. OR; Conduct <u>solar path analysis</u> for windows of AC as well as non-AC spaces, to ensure that the window is completely shaded for the duration between 10:00 am on 1st April to 15:00 on 30th September OR; Any combination of the above strategies on 100% of the fenestrations – Mandatory
Alternative 2
• Demonstrate that the <u>mean DA requirements (300* lux or more)</u> are met over the total living area for at least 25% of total annual analysis hours (area-weighted) – Mandatory • Demonstrate that the mean DA requirements <u>(3000 lux or more)</u> are <u>never exceeded over the total living area</u> for across the total annual analysis hours – Mandatory • Demonstrate that the mean DA requirements (300* lux or more) are met over the total living area for at least <u>50%/75% of total annual analysis hours</u> (area-weighted) – 2/4 points

2.9 ECBC DAYLIGHT STANDARDS

Table 2.8 ECBC Daylight standards

ECBC GUIDELINES-VERTICAL FENESTRATION

ECBC limits the area of vertical fenestration, under the prescriptive approach to a maximum of **60% of gross wall area**.

Climate	Maximum U-factor	WWR≤40%	40% <WWR≤60%
		Maximum SHGC	Maximum SHGC
Composite	3.30	0.25	0.20
Hot and Dry	3.30	0.25	0.20
Warm and Humid	3.30	0.25	0.20
Moderate	6.90	0.40	0.30
Cold	3.30	0.51	0.51

Vertical Fenestration U factor and SHGC requirement

Window Wall Ratio	Minimum VLT
0 - 0.3	0.27
0.31-0.4	0.20
0.41-0.5	0.16
0.51-0.6	0.13

Minimum VLT Requirements

Skylight area is limited to a maximum of **5%** of the gross roof area for the prescriptive requirement. Fenestration slope of less than **60 deg** from horizontal is considered horizontal fenestration.

Climate	Maximum U-factor		Maximum SHGC	
	With Curb	w/o Curb	0-2% SRR	2.1-5% SRR
Composite	11.24	7.71	0.40	0.25
Hot and Dry	11.24	7.71	0.40	0.25
Warm and Humid	11.24	7.71	0.40	0.25
Moderate	11.24	7.71	0.61	0.4
Cold	11.24	7.71	0.61	0.4

Skylight U factor and SHGC requirement

2.10 NBC 2016 ILLUMINATION LEVELS

Table 2.9 NBC lux requirements

20.6	Libraries	
20.6.1	Lending library	
20.6.1.1	General	200-300-500
20.6.1.2	Counters	300-500-750
20.6.1.3	Bookshelves	100-150-200
20.6.1.4	Reading rooms	200-300-500
20.6.1.5	Reading tables	200-300-500
20.6.2	Catalogues	
20.6.2.1	Card	100-150-200
20.6.2.2	Microfiche/Visual display units	100-150-200
20.6.3	Reference libraries	
20.6.3.1	General	200-300-500
20.6.3.2	Counters	300-500-750

CHAPTER 3

CASE STUDY

3.1 LIVE CASE STUDY: ANNA CENTENARY LIBRARY

Building Type: Public / Institutional

Total builtup Area: 41,806 sq.m

Certification Recieved: LEED gold

Architect: C.R.Narayana Rao.

3.1.1 SUSTAINABLE FEATURES

Reading areas facing North and East direction.

Southwest-Thermal buffer zones of service core.

9 storey high atrium for daylight integration.

7 storey Atrium to illuminate the Stack areas.

Landscaped terrace to reduce heat island effect.

Lighting fixtures with daylight and motion sensors.

High performance glazing which optimises daylight and heat penetration.

Pergolas and Metal louvers cut off heat and glare.

3.1.2 ZONING ANALYSIS

Based on the footprint. Approximately 1000-1100 people visit daily.

70-80% of the people use the own book reading section and competitive exam book section. These highly occupied zones are planned in the lower floors to save energy spend on vertical circulation.



Fig 3.1 OAT above Assembly



Fig 3.2 Exterior View

3.1.3 ACCESS ROAD

The access to the site is through Gandhi Manadapam Road (20m).

Baggage Collection point is located at the Pedestrian Entry.

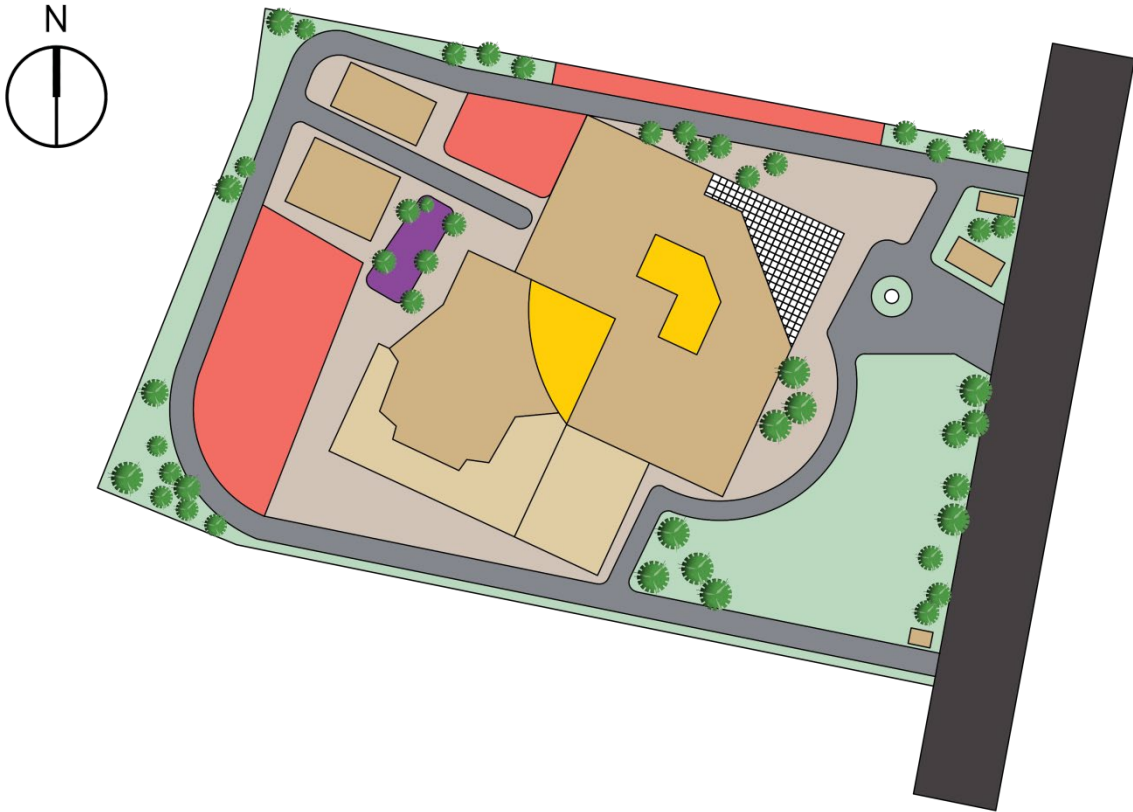


Fig 3.3 Spatial Zoning

3.1.4 SPATIAL ZONING

The auditorium block and the Main library is connected through an Atrium which acts as a transition space.

The auditorium and the amphitheatre has a separate entrance and parking lots on the West.

Outdoor dining area is planned in zone which has existing vegetation cover.

The two wheeler and the 4 wheeler parking for the visitors is provided in the North.

The existing Royal palm trees in the East provide shade during the morning hours avoiding glare.

The landscape planned in the East acts as a noise Buffer.

3.1.5 ZONING ANALYSIS

The Braille Reading Room has been zoned near the entry for barrier free for easy access of the Visually impaired.

The minimally occupied spaces like the Toilets, AHU Rooms, Electrical Rooms, Emergency staircase are planned in the West and South sides to act as a thermal buffer.

The Central atrium starts from the first floor and acts as light well maintaining illumination level of 100-200 lux throughout the day in Main staircase meeting the NBC Standards.

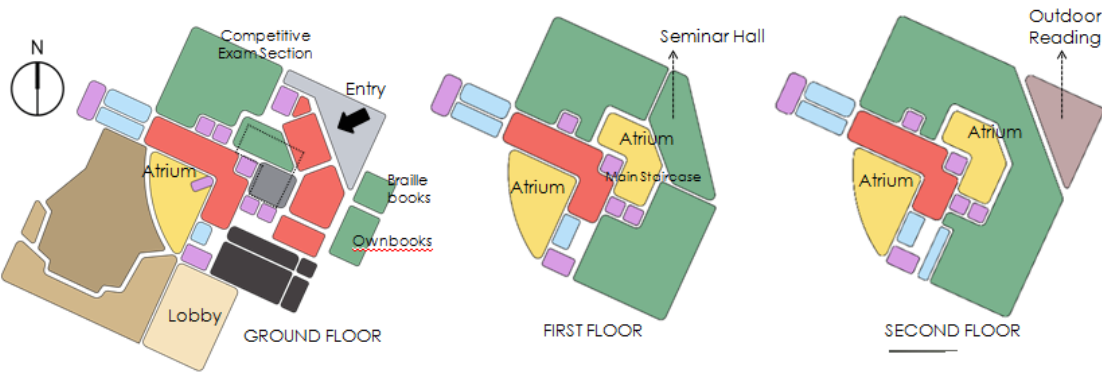


Fig 3.4 Space Planning

LEGEND

- Library space
- Lobby and Corridor
- Atrium
- Circulation
- Service
- Assembly
- Assembly-2



Fig 3.5 Interior Views

3.2 CASE STUDY 2- *Library and Cultural Centre-Fritz Hansen Factory-Denmark*

Firm: Primus Arkitekter

The extension is divided along its length into two spaces. The children's library occupying the side, adjoins the brick building housing the main library.



Fig 3.6 Library and cultural centre

A sawtooth roof with integrated skylights and solar panels gives this library and cultural centre in Denmark an industrial aesthetic. The project is an adaptive reuse of an old furniture factory.

Both spaces feature high, sloping ceilings with integrated skylights that illuminate the interiors and help improve acoustics within the large rooms. Spatial generosity and abundance of natural light -Open floor plan was adopted with ceiling of varying height.



Fig 3.7 Ground floor plan-Library and cultural centre

3.4 CASE STUDY 4-BISHAN PUBLIC LIBRARY

Location: Singapore

Architect: Look Architects

Area: 1400 sq.m

Year: 2016

The library is raised above the anonymity of its mixed used neighbourhood. The design was conceptualised to be a metaphor of a tree house. The daylight was integrated through the use of Skylights, Trellises and Tinted glass. It created an effect of light filtered through tree foliage.



Fig 3.8 Bishan Public library

'Pods' cantilevered off the main building facade exude a distinctive charisma on the exterior. It create suspended alcoves at an intimate scale from the building. An internal atrium was incorporated to introduce natural daylight deep into the main circulation zone. The back-of-house was on the western elevation that also serves to shield the building from the harsh evening sun.

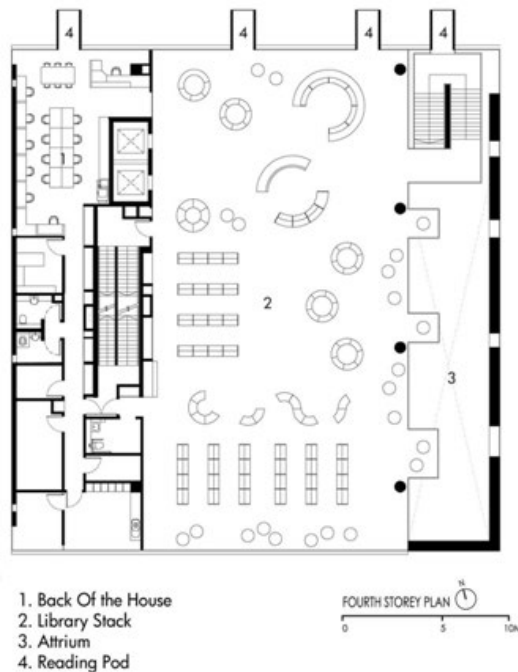


Fig 3.9-Ground floor plan-Bishan Public library

3.5 CASE STUDY 4- Lilavathi Lalbhai Library

Location: Ahmadabad, India

Architect: RMA Architects

Area: 31,000 sq.m (G+2)

Year: 2017

Embedded in the heart of the CEPT University campus it has entrances facing 4 cardinal directions. The modulated, louvered facade can be manually adjusted to allow in less light or more ventilation in response to Ahmadabad's severely hot and dry climate.



Fig 3.10 Lilavathi lalbhai library

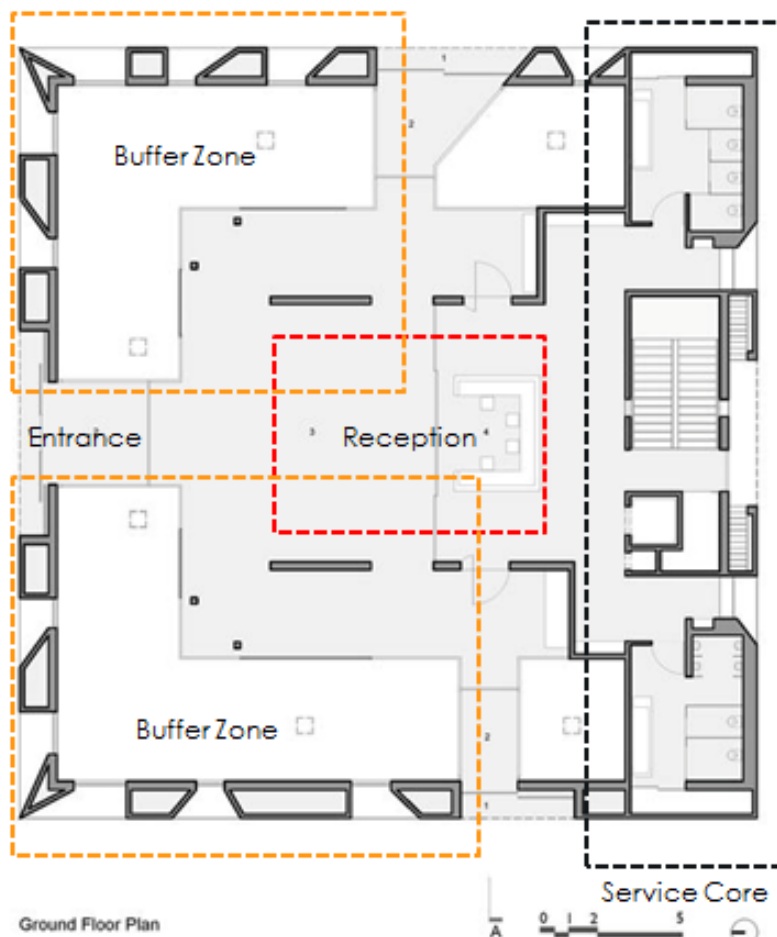


Fig 3.11 Ground floor plan-Lilavathi lalbhai library

CHAPTER 4

SITE ANALYSIS

4.1 SUN PATH AND WIND DIRECTION

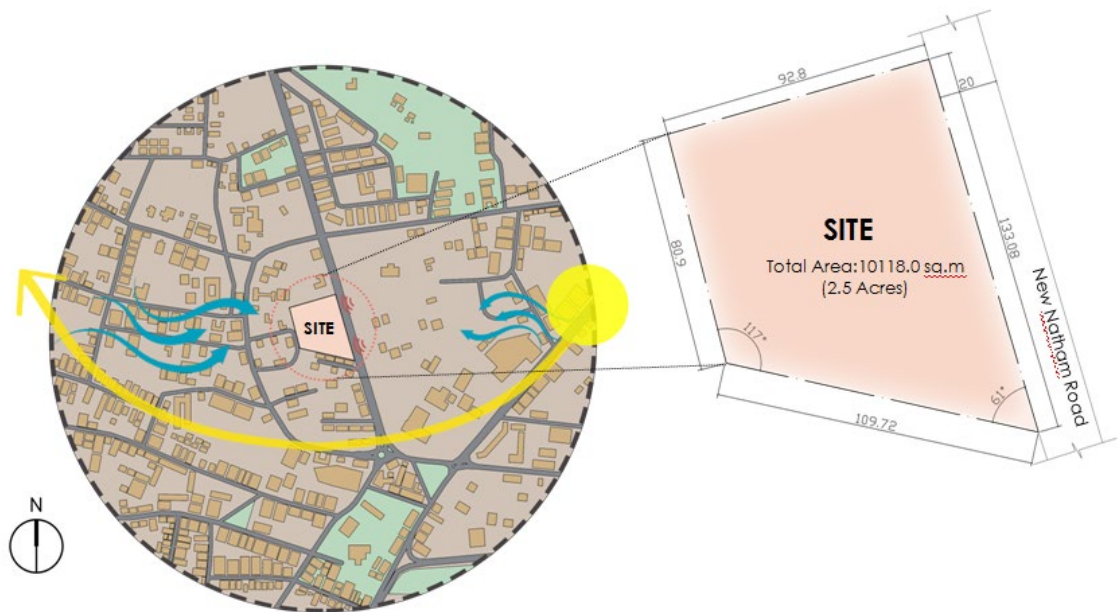


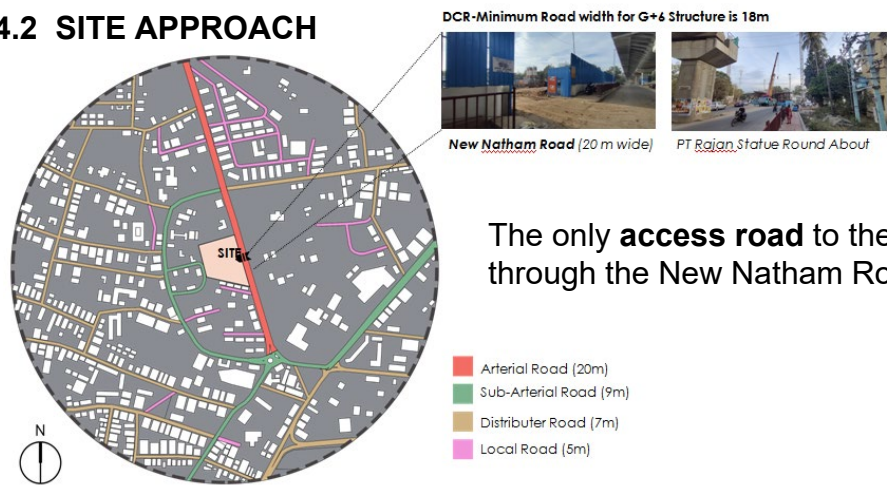
Fig 4.1 Sun path and Wind direction

Table 4.1 Wind data

WIND DATA	
Direction	Duration
West	May-Mid Oct
East	Jan-Apr
North	Oct-Jan

The site is N-S oriented. The building should be oriented with longer side facing North-South direction to protect from the solar radiation.

4.2 SITE APPROACH



The only **access road** to the site is through the New Natham Road.

Fig 4.2 Site Approach

4.3 BUILDING TYPOLOGY AND LANDUSE

The site comes under the Residential Land use and flanked by public zone. The site has closer proximity to Educational Institutions within 1 km radius. The site has dense residential zone towards the South.

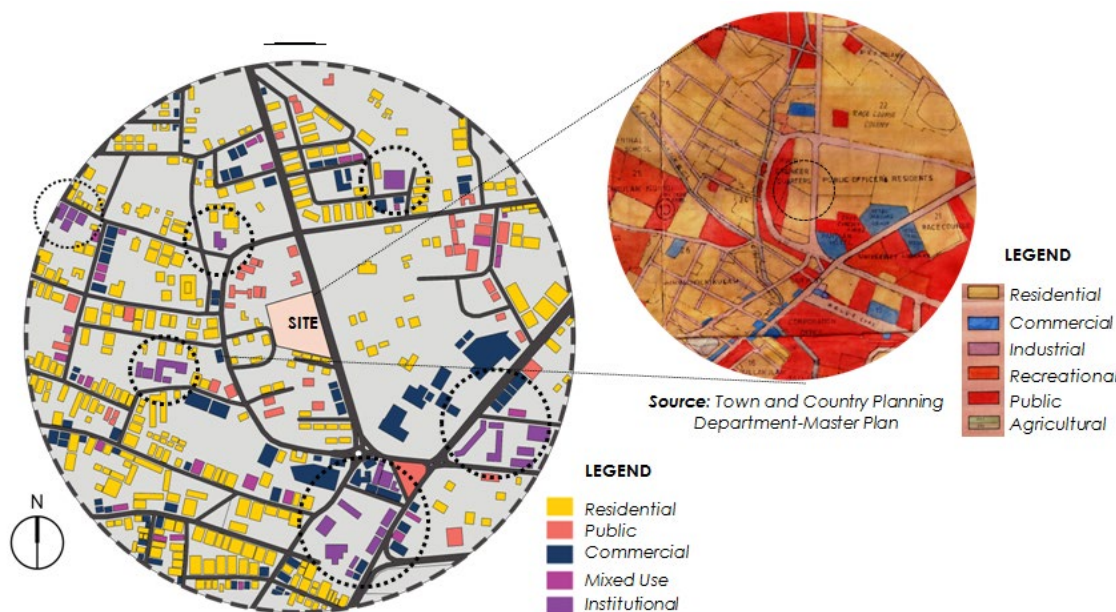


Fig 4.3 Building typology and landuse

4.4 CONTOUR AND VEGETATION

The site has an undulating mild slope towards the West. The type of soil found in the site is Clay loam. It is an ideal soil type for construction as it is evenly balanced. The site is surrounded by dense vegetation on North, South and West. Scattered vegetation is found on the East.

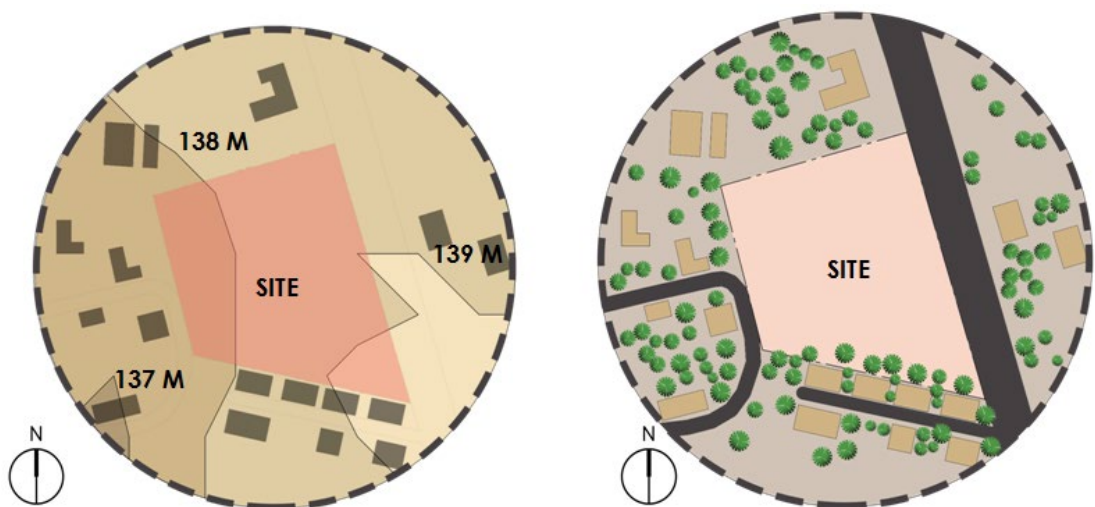


Fig 4.4 Contour and vegetation

4.5 SHADOW ANALYSIS

As the site is not surrounded by high rise structures no shadow falls on the site. The site has G+2 Apartment blocks towards the South.

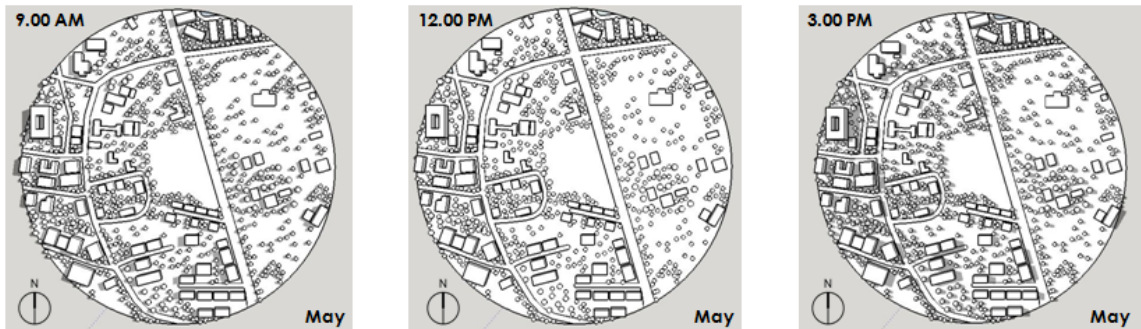


Fig 4.5 Shadow Analysis

4.6 RADIATION ANALYSIS

As there is no existing vegetation present in the Site, the ground is exposed to direct radiation all through the year..

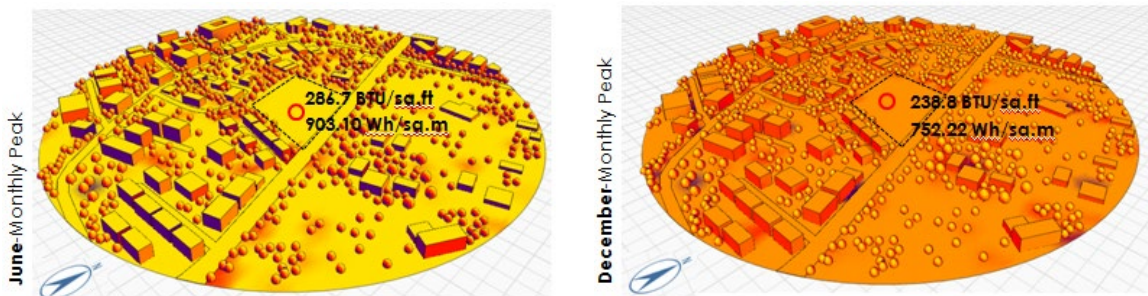


Fig 4.6 Radiation Analysis

4.7 DESIGN STRATEGIES



Fig 4.7 Design Strategies

4.8 WIND ANALYSIS

The surrounding buildings are spread out with large open spaces in the East, West and North. This allows unrestricted air movement. The building should be oriented to catch the available air movement. As Madurai lies in Warm and humid zone, most part of the year is muggy.



Fig 4.8 Figure Ground Map

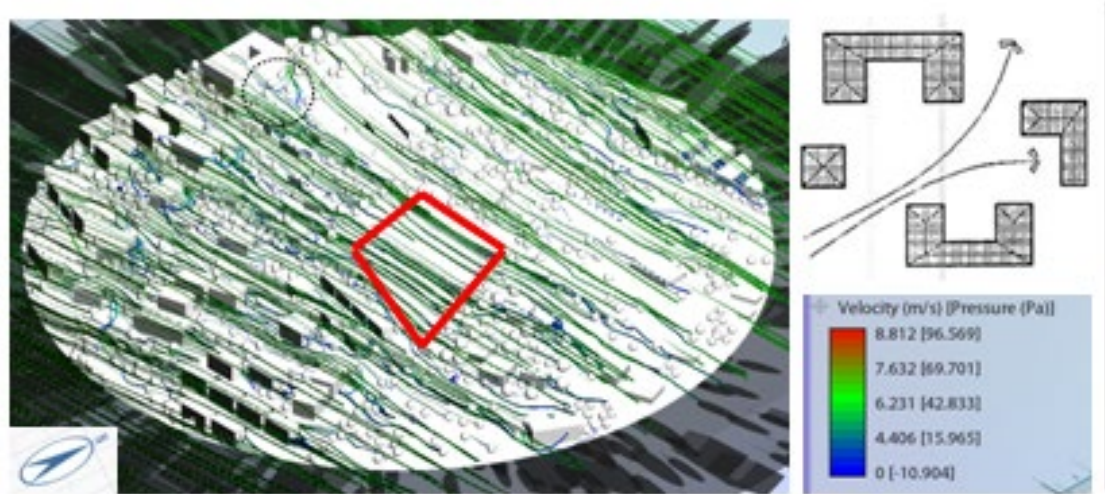


Fig 4.9 Wind analysis

4.9 AREA STATEMENT

Table 4.2 Area statement

S.NO	SPACE	AREA IN SQ.M
1.	Entrance Lobby	140 sq.m
2.	New Member Registration	20 sq.m
3.	Cloak Room	20 sq.m
4.	Server Networking Control	100 sq.m
5.	Return Counter	15 sq.m
6.	Issue Counter	15 sq.m
7.	Tapal Section	15 sq.m
8.	Record and Store	40 sq.m
9.	Office and Security	40 sq.m
10.	Differently Abled Section	200 sq.m
11.	Multi-purpose hall	350 sq.m
12.	VIP Lounge	30 sq.m
13.	Own book Reading Section	100 sq.m
14.	Conference hall	350 sq.m

S.NO	SPACE	AREA IN SQ.M
15.	VIP Lounge	30 sq.m
16.	Green Room	20 sq.m
17.	Periodicals and Magazine Section	700 sq.m
18.	Children Section	700 sq.m
19.	Reprographics Section	20 sq.m
20.	Kids Performance Centre	180 sq.m
21.	Kalaiginar Section	250 sq.m
22.	Own book Reading Section	200 sq.m
23.	Tamil books Section	3000 sq.m
24.	English Book Section	2000 sq.m
25.	Rare Book Section	200 sq.m
26.	Multimedia Room	100 sq.m
27.	Digital Library	200 sq.m
28.	English Section Reference	500 sq.m

S.NO	SPACE	AREA IN SQ.M
29.	Research paper and Journal	200 sq.m
30.	English Section	675 sq.m
31.	Competitive Exam Section	675 sq.m
32.	Digitalisation Chamber	90 sq.m
33.	Microfiche Chamber	85 sq.m
34.	Digital Studio for Visually Impaired	80 sq.m
35.	Chief Librarian Office	220 sq.m
36.	Stores and Record	30 sq.m
37.	Office	30 sq.m
38.	Librarian Office	40 sq.m
39.	Board Room	100 sq.m
40.	Cataloguing Section	220 sq.m
41.	Book Binding Section	180 sq.m
42.	Procurement Section	220 sq.m

S.NO	SPACE	REQUIRED NO.S
43.	Toilets (Male)	4 per floor
44.	Toilets (Female)	4 per floor
45.	Toilet (Differently abled)	1 per floor
46.	Lift	4+1 service lift
47.	Parking	Car-100, Bike-200

Site Area	1,01,180 sq.m
Ground Coverage	5100 sq.m
OSR	450 sq.m
Floor height	3.9 m
Total height	30 m

CHAPTER 5 DESIGN DEVELOPEMENT

5.1 ZONING

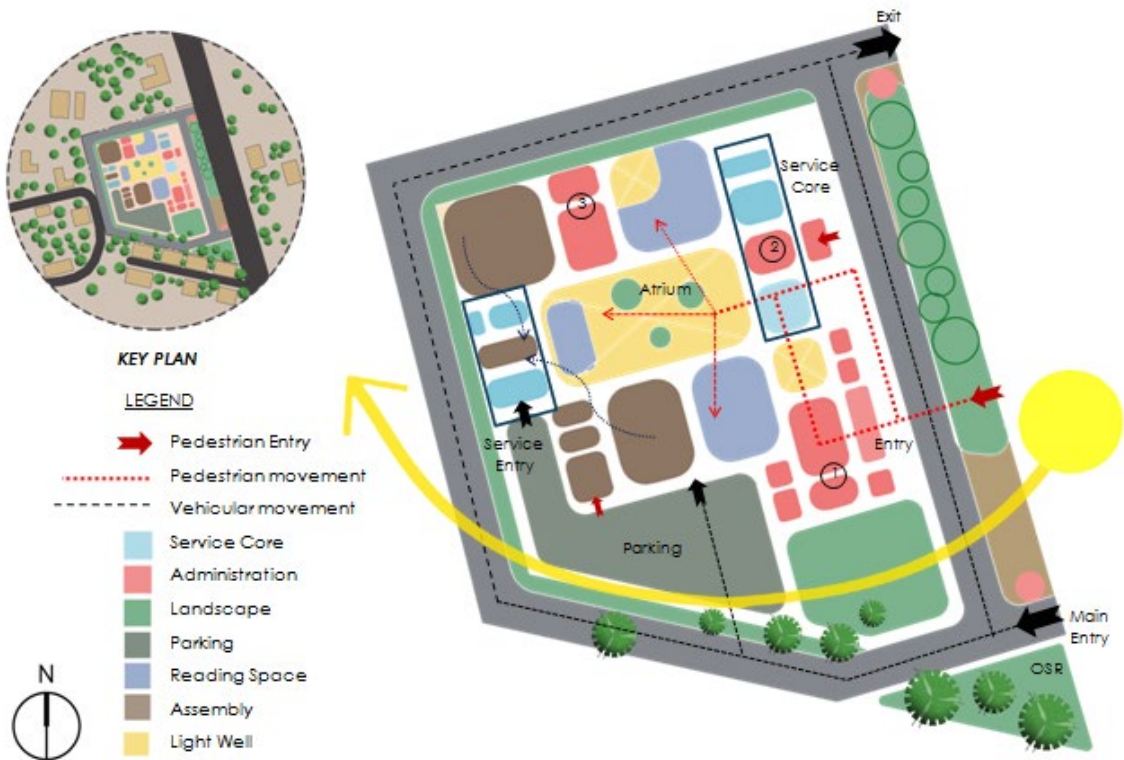


Fig 5.1 Iteration 3

ADMIN-1 ▪ Entrance Lobby ▪ New Member Registration ▪ Issue Counter ▪ Return Counter ▪ Tapal Section ▪ Office ▪ Record Storage	ADMIN-2 ▪ Waiting Lobby ▪ Reader's Entry ADMIN-3 ▪ Server Control ▪ Security
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The Reading areas are oriented towards the North and South for desired day lighting and to cut down discomfort glare.

The Central Atrium serves as a light level to the adjacent reading spaces.

The Service core zoned on the East serves as a Thermal and Acoustic buffer.

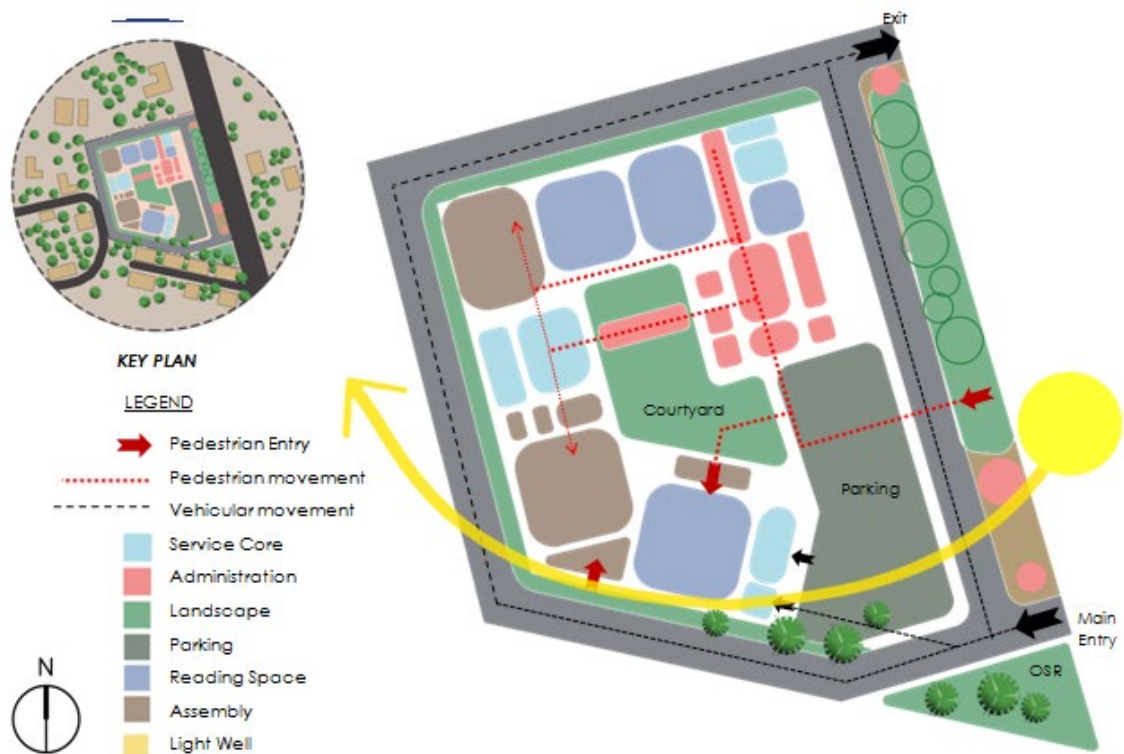


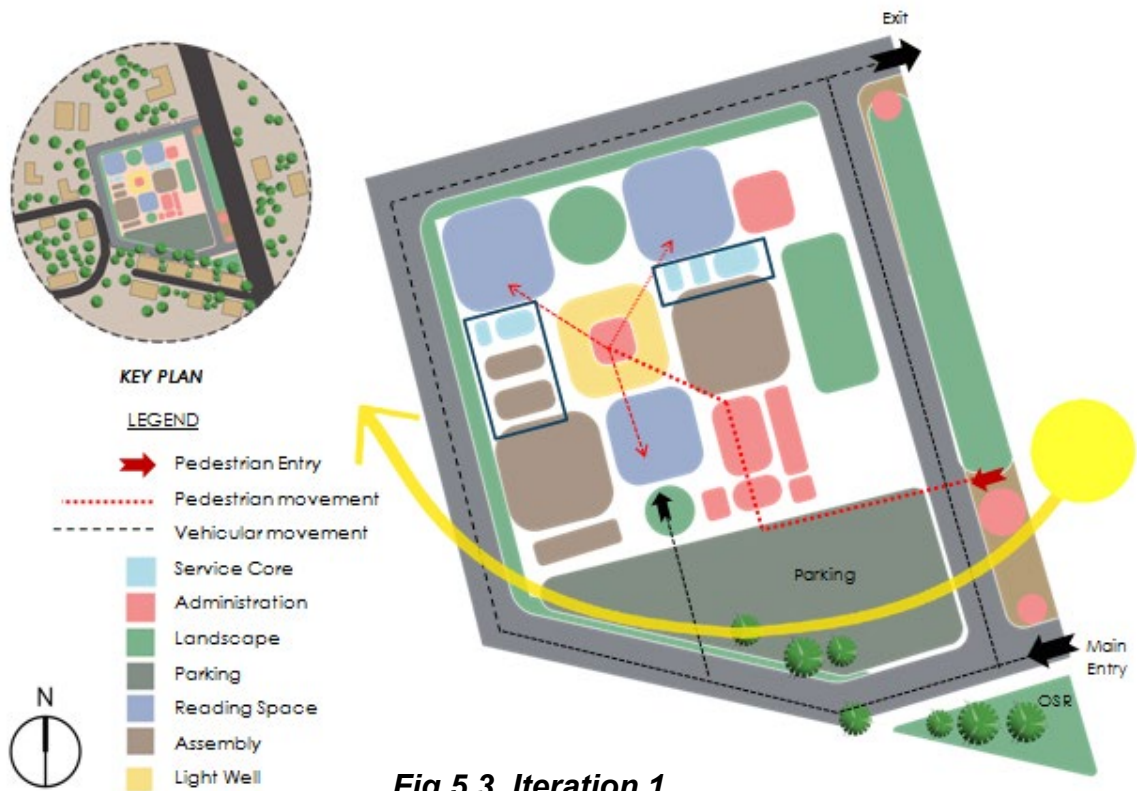
Fig 5.2 Iteration 2

	ADMIN-1	ADMIN-2
	▪ Entrance Lobby	▪ Waiting Lobby
	▪ New Member Registration	▪ Reader's Entry
	▪ Issue Counter	
	▪ Return Counter	
	▪ Topical Section	ADMIN-3
	▪ Office	▪ Server Control
	▪ Record Storage	▪ Security

The Central Courtyard links the Admin, Reading and the Assembly zones together integrating nature.

This provides effective daylight integration due to thin floor plate and more provision for ambient lighting.

The form derived out of the zoning was found to have high exposed surface area contributing to heat gain.



■	ADMIN-1	ADMIN-2
■	▪ Entrance Lobby	▪ Waiting Lobby
■	▪ New Member Registration	▪ Reader's Entry
■	▪ Issue Counter	
■	▪ Return Counter	ADMIN-3
■	▪ Taped Section	▪ Server Control
■	▪ Office	▪ Security
■	▪ Record Storage	

The Reading areas are oriented towards the North and South for desired day lighting and to cut down discomfort glare.

The outdoor reading spaces (balconies) which opens towards the North courtyard were affected by Radiation and reduce the daylight penetration.

The Assembly areas are not segregated based on the user footprint.

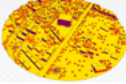
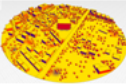
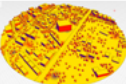
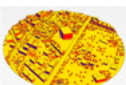
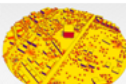
5.1.1 COMPARITIVE ANALYSIS

Table 5.1 Zoning-Comparitive Analysis

S.No	FACTORS	ITERATION-1	ITERATION-2	ITERATION-3
1.	Zoning			
2.	Energy Efficiency	- The light well in the North contributes to solar heat gain. - Assembly spaces cant be thermally zoned together.	The spaces are not compactly planned leading to greater exposed surface area contributing to heat ingress.	- The Central Atrium works best for Warm and humid climatic condition as it allows least radiation. - Proper thermal zoning of spaces.
3.	User Comfort	The outdoor reading areas are affected by noise due to noise hazard and radiation.	- The outdoor reading balconies are inward looking towards the central courtyard. - Potential for glare from morning sun.	- The reading balconies opens into the central atrium space, which has least exposure to solar radiation. - No noise hazard in the indoor space.
4.	Daylight	The attached courtyard in the North acts as a light well only to the reading spaces.	The Central Courtyard provides ample daylight but can cause glare and increased radiation heat gain.	The Staggered Central Atrium provides deeper penetration of daylight into interior spaces
5.	Ventilation	No provision for Stack effect during non-air conditioned functioning of the building.	Cross ventilation is possible due to open planning which is suitable for Warm and humid climatic condition.	- Stack effect is achieved through the Central atrium planning. - Strategic planning of openings.
6.	Functionality	The Assembly areas hinder the reader population visiting the library spaces.	Lesser connectivity between the Reading area wings and longer travel distances.	Proper segregation of the user footprint for lesser traffic and efficient connectivity.

5.2 BLOCK ORIENTATION ANALYSIS

Table 5.2 Block Orientation Analysis

ORIENTATION	SIMULATION	NORTH	SOUTH	EAST	WEST	ROOF	CUMULATIVE RADIATION
0 degree (BASE CASE)		89.15 BTU/sq.ft	25.19 BTU/sq.ft	224.3 BTU/sq.ft	119 BTU/sq.ft	286.7 BTU/sq.ft	457.64 BTU/sq.ft
15 degree		78.94 BTU/sq.ft	24.52 BTU/sq.ft	232.4 BTU/sq.ft	106.5 BTU/sq.ft	286.7 BTU/sq.ft	442.36 BTU/sq.ft 4% decrease
30 degree		100.1 BTU/sq.ft	60.14 BTU/sq.ft	224.3 BTU/sq.ft	86.69 BTU/sq.ft	286.7 BTU/sq.ft	471.23 BTU/sq.ft 3% increase
45 degree		114.8 BTU/sq.ft	116.2 BTU/sq.ft	201.8 BTU/sq.ft	61.71 BTU/sq.ft	286.7 BTU/sq.ft	494.51 BTU/sq.ft 8% increase
60 degree		114.8 BTU/sq.ft	116.2 BTU/sq.ft	201.8 BTU/sq.ft	61.71 BTU/sq.ft	286.7 BTU/sq.ft	490.99 BTU/sq.ft 7.2% increase

5.3 FORM FACTOR ANALYSIS

Form Factor is the ratio between the building’s envelope area (EA) and it’s net floor area (NFA).

It is calculated as $FF = EA / NFA$

5.3.1 DESIGN RECOMMENDATION

Compact form with low S/V ratio is recommended.

A square plan with a courtyard would be very effective.

A rectangular form with a longer axis along the north-south is the preferred orientation. East and west orientation should be protected by buffer spaces, shaded walls.

5.3.2 METHODOLOGY

- 1. 10 different forms having floor area of 3600 sq.m was chosen.
- 2. The height of the form was taken as 27.3 m considering G+7 structure.
- 3. The calculated form factor is compared and analysed.

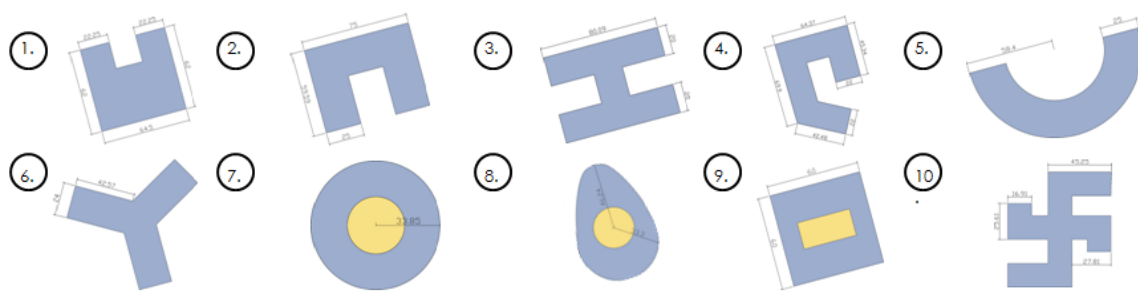
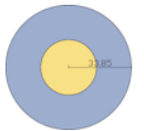
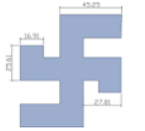
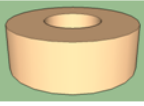


Fig 5.4 Form factor analysis comparison

Table 5.3 Form factor analysis comparison

OPTIONS	ITERATION 1	ITERATION 2	ITERATION 3	ITERATION 4	ITERATION 5
2D Form					
3D Model					
Form factor	$HLF=EA/NFA$ $= 14054.2/25200$ $= 0.55$	$HLF=EA/NFA$ $= 15126.46/25200$ $= 0.60$	$HLF=EA/NFA$ $= 16575.38/25200$ $= 0.65$	$HLF=EA/NFA$ $= 15919.54/25200$ $= 0.63$	$HLF=EA/NFA$ $= 15122.12/25200$ $= 0.61$
Inference	The Rectilinear form with an Attached courtyard in the north receives high radiation.	The C shaped form helps in an introverted planning focussing on central courtyard.	The form has two wings extending in North-South orientation. The central wind serves as circulation core.	The form is derived from the site and the South wind receives higher radiation.(30 degree)	The semicircular form extends in N-S direction but its is not compact.

Table 5.4 Form factor analysis comparison

OPTIONS	ITERATION 6	ITERATION 7	ITERATION 8	ITERATION 9	ITERATION 10
2D Form					
3D Model					
Form factor	$HLF=EA/NFA$ $= 15385.71/25200$ $= 0.61$	$HLF=EA/NFA$ $= 12080/25200$ $= 0.47$	$HLF=EA/NFA$ $= 12413.57/25200$ $= 0.49$	$HLF=EA/NFA$ $= 11611.2/21.700$ $= 0.51$	$HLF=EA/NFA$ $= 18441.59/25200$ $= 0.73$
Inference	The form facilitates Radial planning. The wings could become the reading spaces.	The spherical form is the most compact and suitable for Warm and humid climate.	The pyriform has comparatively lower heat gain factor but it may hinder the circulation.	The Rectilinear form with a Central atrium is more compact and receives less heat gain.	The Swastik form is more open but has larger surface exposed to solar heat gain.

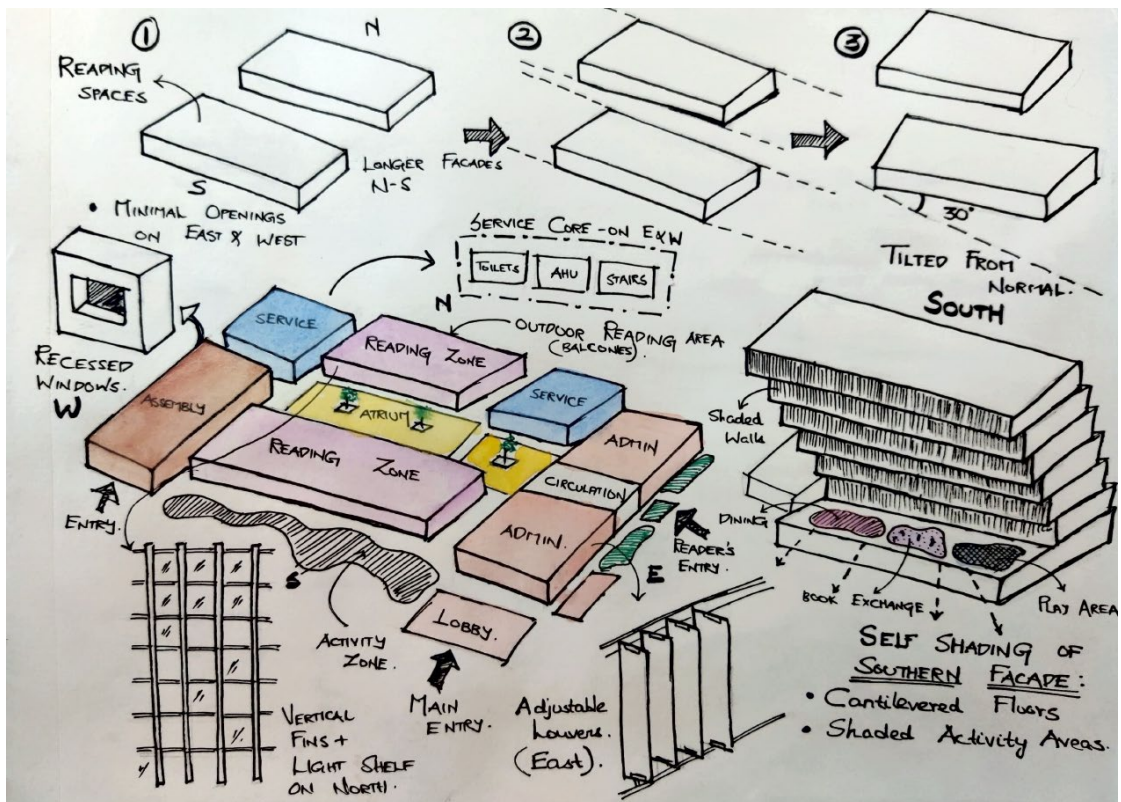


Fig 5.5 Design Ideas

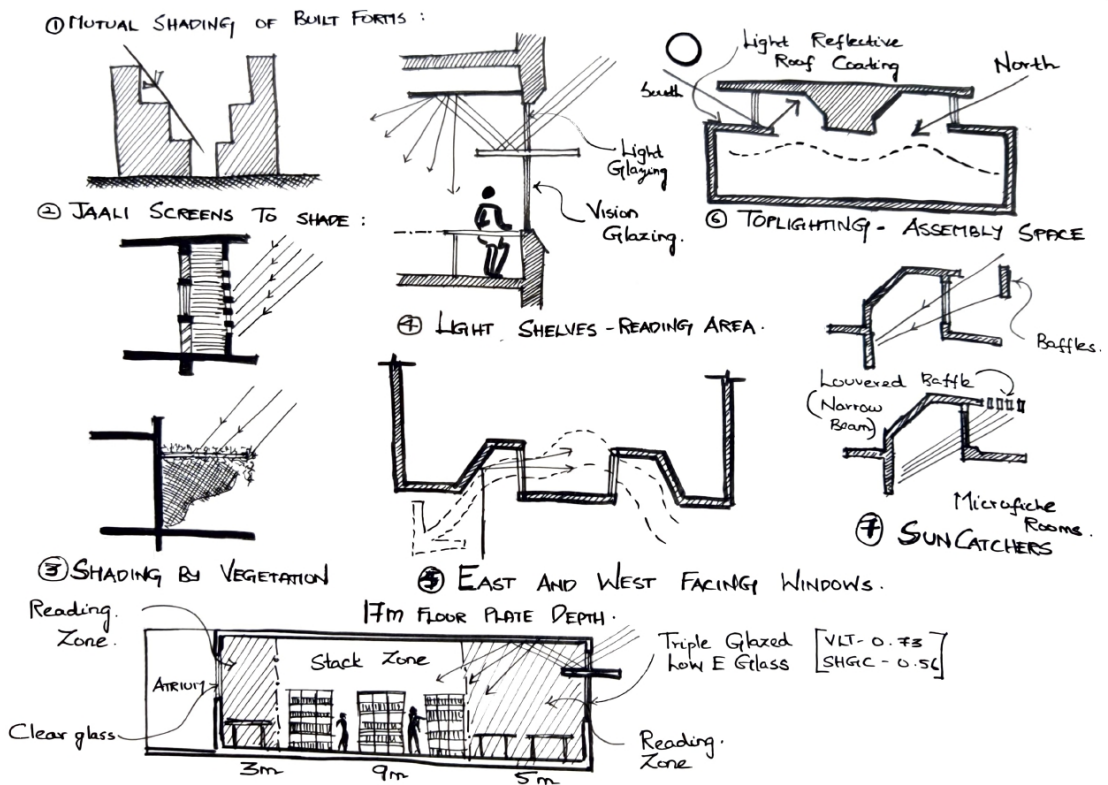


Fig 5.6 Design strategies

5.4 OPTIMISATION OF FLOOR PLATE DEPTH

To find the optimum depth of floor plate for effective daylight penetration. To analyse the effect of shading device on daylight performance. To find the effect of light shelf as a passive strategy to improve day lighting. To compare the simulation results with the Green Rating standards for day lighting.

5.4.1 DAYLIGHTING METRICS FOR GREEN RATING

LEED Rating-Spatial Daylight Autonomy

GRIHA-Daylight Autonomy and UDI

IGBC-Point in time illuminance

WELL Building Standards-sDA and ASE.

5.4.2 METHODOLOGY

A 25m x 25m reading space is considered.

The block is oriented 15 degree from normal

Shading device based on SP 41 calculations.

5.4.3 ASSUMPTIONS

The window sill level is taken as 0.9m which is the work plane level.

The height of the window is taken as 2.3 m.

The glazing material used in the model is Triple glazed Low E glass.

The visible light transmittance (VLT) value is taken as 0.70.

The solar heat gain co-efficient (SHGC) is taken as 0.53

For Point in time illuminance simulation September 12 noon time period is taken. Vertical fins of depth 0.5m and 1m spacing is added.

Table 5.5 Optimisation of floor plate depth step 1

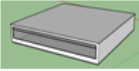
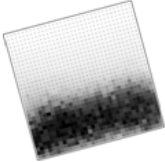
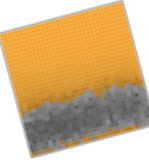
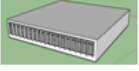
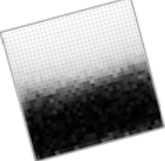
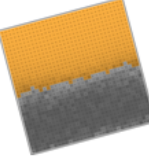
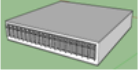
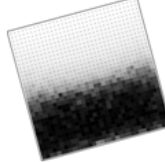
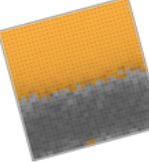
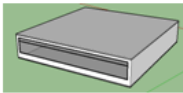
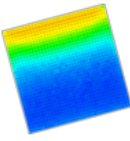
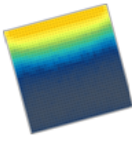
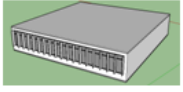
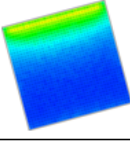
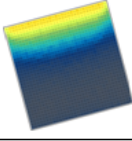
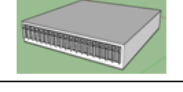
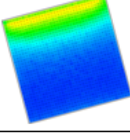
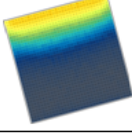
ITERATIONS	Daylight Autonomy (DA) 	Spatial Daylight Autonomy 	Annual Solar Exposure 
1. Windows 	 DA: 66.89 %	 sDA: 66.67 %	 ASE: 7.9 %
2. Windows with Shading device (As per SP 41) 	 DA: 52.32 % 21.78% decrease	 sDA: 52.16 % 21.76% decrease	 ASE: 0.83 % 89.49 % decrease
3. Windows with shading device and light shelf 	 DA: 55.37 % 5.83% increase	 sDA: 55.19 % 5.81% increase	 ASE: 0.00 %

Table 5.6 Optimisation of floor plate depth step 2

ITERATION	Point in time illuminance 	Daylight Factor (DF) 
1. Windows 	 Average lux: 341.3 lux	 Average DF: 2.2 %
2. Windows with Shading device 	 Average lux: 212.3 lux 37.8 % decrease	 Average DF: 1.3 % 40.91 % decrease
3. Windows with shading device and light shelf 	 Average lux: 242.9 lux 14.41 % increase	 Average DF: 1.6 % 23.08 % increase

It is found that for a window of height 2.6m, the depth of daylight penetration (Reading space: 300 lux) would be 10.3m. By thumb rule the depth of penetration would be twice the window height which is 12.4m. The addition of appropriate shading device would decrease the illuminance by 25%-35%.

Table 5.7 Optimisation of floor plate depth step 3

ITERATIONS	Daylight Autonomy (DA)	Spatial Daylight Autonomy	Annual Solar Exposure
1. 25m floor plate depth with Atrium	 DA: 58.17 % DA: 41.69 % DA: 72.78 %	 sDA: 58.71 % sDA: 40.66 % sDA: 78.65 %	 ASE: 37.09 % ASE: 6.98 % ASE: 7.47 %
2. 20m floor plate depth with atrium	 DA: 70.18 % DA: 61.73 % DA: 89.05 %	 sDA: 70.16 % sDA: 59.80 % sDA: 97.06 %	 ASE: 42.12 % ASE: 9.45 % ASE: 9.54 %
3. 17m floor depth with atrium	 DA: 75.34 % DA: 60.57 % DA: 90.75 %	 sDA: 76.12 % sDA: 58.77 % sDA: 100 %	 ASE: 47.68 % ASE: 8.55 % ASE: 11.58 %

ITERATIONS	Point in time illuminance	Daylight Factor (DF)	UDI
1. 25m floor plate depth with Atrium	 Avg lux: 313.6 lux Avg lux: 264.4 lux Avg lux: 555.3 lux	 Avg DF: 2.3 % Avg DF: 1.2 % Avg DF: 1.6 %	 UDI-a: 68.85 % UDI-a: 80.29 % UDI-a: 88.17 %
2. 20m floor plate depth with atrium	 Avg lux: 345.8 lux Avg lux: 353.1 lux Avg lux: 727 lux	 Avg DF: 2.3 % Avg DF: 1.7 % Avg DF: 2.1 %	 UDI-a: 76.06 % UDI-a: 76.06 % UDI-a: 76.06 %
3. 17m floor depth with atrium	 Avg lux: 376.1 lux Avg lux: 337.5 lux Avg lux: 485.8 lux	 Avg DF: 2.9 % Avg DF: 2.1 % Avg DF: 2.2 %	 UDI-a: 90.12 % UDI-a: 92.13 % UDI-a: 93.10 %

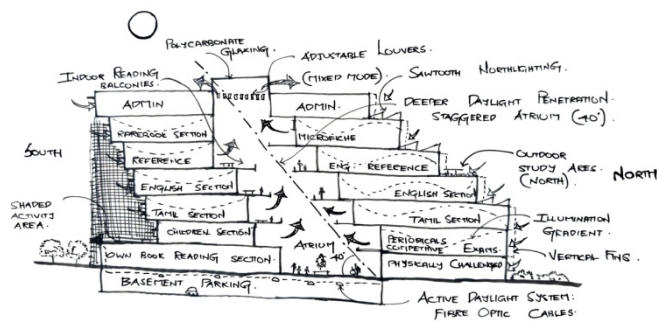


Fig 5.7 Conceptual Section

5.5 SHADOW ANALYSIS

Table 5.8 Shadow Analysis-Iteration Comparison

Base Case: SOUTH FACADE-FLAT-WITHOUT STAGGERED FORM

MONTH	MARCH	APRIL	DECEMBER
9.00 AM			
12.00 PM			
3.00 PM			

Iteration 1: SOUTH FACADE 0.5M STAGGERING ON EACH FLOOR

MONTH	MARCH	APRIL	DECEMBER
9.00 AM			
12.00 PM			
3.00 PM			

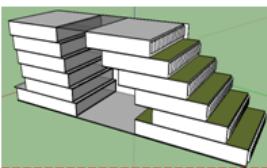
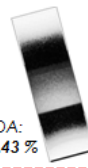
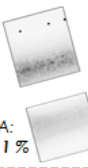
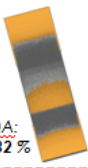
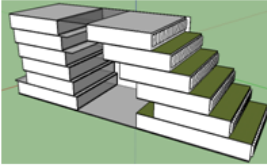
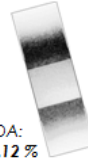
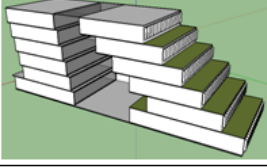
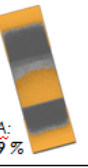
Iteration 2: SOUTH FACADE 1M STAGGERED FORM

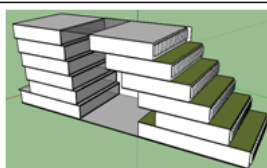
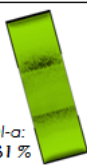
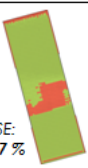
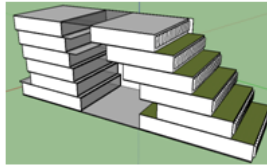
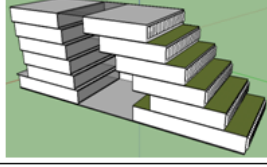
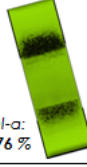
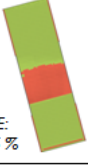
MONTH	MARCH	APRIL	DECEMBER
9.00 AM			
12.00 PM			
3.00 PM			

The Ground Floor extends as the Outdoor Reading Area which is shaded by the cantilevered floors above. Iteration 1 has a cantilever projection of length 0.5m. Iteration 2 has cantilever projection of length of 1m. It was found that during the period from February-March, 1m projection completely shades the wall cutting down heat gain during all times of the day. During April to August the outdoor reading area is benefitted by self shading of the form. (5 month period including critical months). 0.5m projection is not able to completely self shade the walls and the outdoor reading area below. During the period from November to January self shading is not achieved. The radiation is also comparatively low during these months.

5.6 ATRIUM GEOMETRY OPTIMISATION

Table 5.9 Atrium geometry optimisation

ITERATIONS	3D Model-Staggered Atrium	Daylight Autonomy (DA) 	Spatial Daylight Autonomy (sDA) 
1. Atrium size 20m x 8.5m Polycarbonate Sheet - VLT-0.73 - SHGC-0.58 - SRR-4.7		 DA: 51.43 %  DA: 90.11 %	 sDA: 53.32 %  sDA: 99.23 %
2. Atrium size 20m x 9.5m Polycarbonate Sheet - VLT-0.73 - SHGC-0.58 - SRR-5%		 DA: 75.12 %  DA: 94.86 %	 sDA: 77.32 %  sDA: 99.86 %
3. Atrium size 20m x 10.5m Polycarbonate Sheet - VLT-0.73 - SHGC-0.58 - SRR-5.8%		 DA: 56.25 %  DA: 92.07 %	 sDA: 58.39 %  sDA: 98.76 %

ITERATIONS	3D Model-Staggered Atrium	Useful daylight Illuminance 	Annual Solar Exposure 
1. Atrium size 20m x 8.5m Polycarbonate Sheet - VLT-0.73 - SHGC-0.58 - SRR-4.7%		 UDI-a: 77.61 %  UDI-a: 75.43 %	 ASE: 1.27 %  ASE: 24.47 %
2. Atrium size 20m x 9.5m Polycarbonate Sheet - VLT-0.73 - SHGC-0.58 - SRR-5%		 UDI-a: 91.98 %  UDI-a: 80.14 %	 ASE: 2.35 %  ASE: 21.46 %
3. Atrium size 20m x 10.5m Polycarbonate Sheet - VLT-0.73 - SHGC-0.58 - SRR-5.7%		 UDI-a: 70.76 %  UDI-a: 78.04 %	 ASE: 3.15 %  ASE: 24.52 %

CHAPTER 6 DETAILED DESIGN

6.1 SITE PLAN



Fig 6.1 Site Plan

6.1 SUSTAINABLE FEATURES

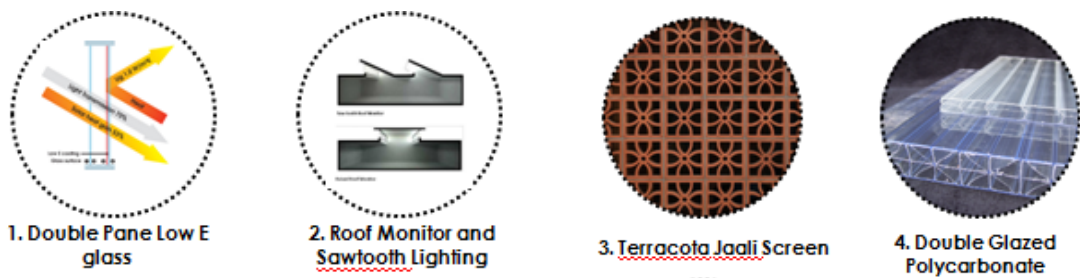


Fig 6.2 Sustainable features

6.3 FLOOR PLANS

Floor Area: 3320 sq.m



Fig 6.3 Ground floor plan

6.3 FLOOR PLANS



Fig 6.4 First floor plan

6.3 FLOOR PLANS



Fig 6.5 Second floor plan

6.3 FLOOR PLANS



Fig 6.6 Third floor plan

6.3 FLOOR PLANS



Fig 6.7 Fourth floor plan

6.3 FLOOR PLANS



Fig 6.8 Fifth floor plan

6.3 FLOOR PLANS



Fig 6.9 Sixth floor plan

6.4 DESIGN OF SHADING DEVICES

The shading devices were designed based on the recommendations from SP41.

SOUTH FACADE:

Window Type 1: 33.23m x 2.3m

Window Type 2: 13.2m x 1.15m

Horizontal Member:

By Table 10, $H(B = 0 \text{ degree})$.

The spacing between the horizontal member is given as $2.75P$, where P is the length of the projection.

1. *Window Type 1: (33.23m x 2.3m)*

$2.75 \times P = \text{Spacing}$

$P = 230/2.75$

$P = 86.63 \text{ cm}$

Two horizontal shading members of length 42 cm is suggested.

2. *Window Type 2: (13.2m x 1.15m)*

$P = 115/2.75$

$P = 41 \text{ cm}$

One horizontal shading device of length 41 cm is suggested.

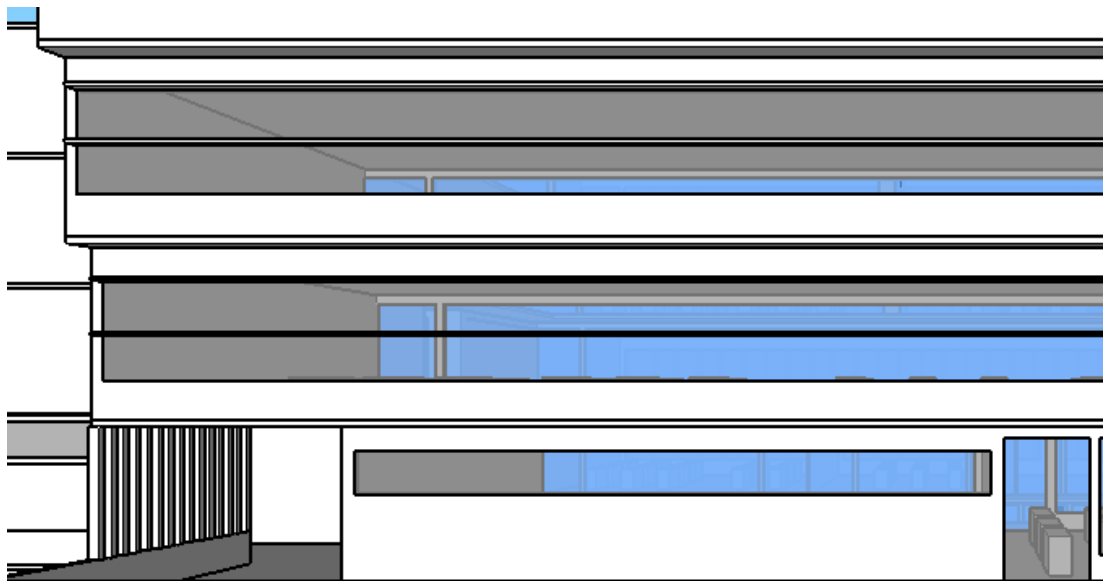


Fig 6.10 View of South facade

NORTH FACADE:

Window Type 1: 32.70m x 2.3m

Window Type 2: 0.7m x 2.9m

Window Type 3: 2m x 1.6m

Vertical Member:

By Table 10, $V(B = 0 \text{ degree})$.

The spacing between the vertical member is given as $2.75P$, where P is the length of the projection.

1. Window Type 1: (32.70m x 2.3m)

$2.75 \times P = \text{Spacing}$

$P = 3270/2.75$

$P = 1189 \text{ cm}$

24 Vertical shading members of length 50 cm is suggested.

2. Window Type 2: (0.7m x 2.9m)

$P = 70/2.75$

$P = 25.45 \text{ cm}$

One Vertical shading device of length 26 cm is suggested.

3. Window Type 3: (2m x 1.6m)

$P = 200/2.75$

$P = 72.72 \text{ cm}$

Two Vertical shading device of length 37 cm is suggested.

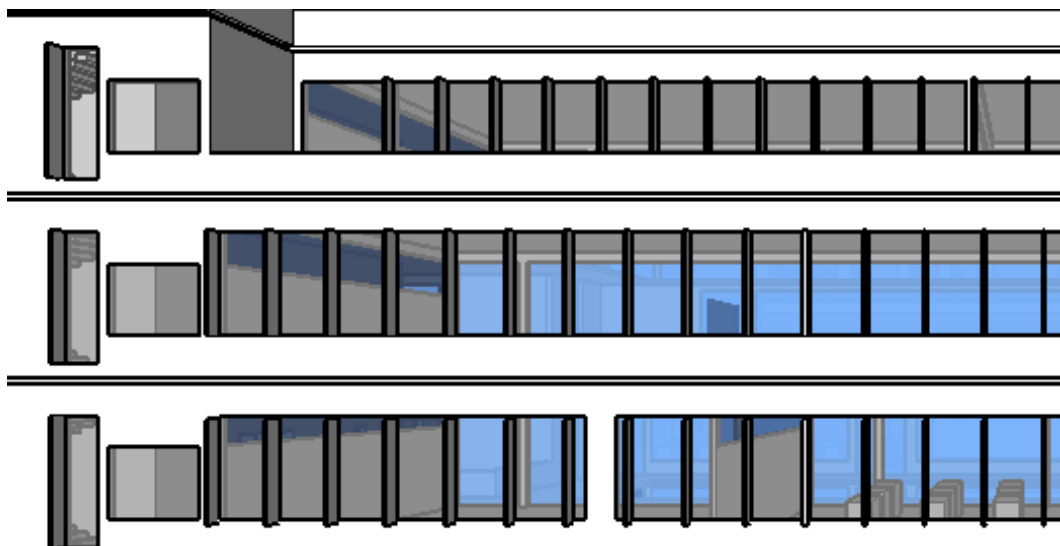


Fig 6.11 View of North facade

EAST FACADE:

Window type 1: (1m x 1.4m)

Window type 2: (1m x 2.3m)

Combination Type of Shading device:

Window Type 1:

By Table 10, $V(B = 60 \text{ degree})$ and $H(B=15 \text{ degree})$.

The spacing between the Vertical members is given by $1.46 P$, where p is the length of the projection.

For vertical member : $P = 100/1.46$

$P = 68.5 \text{ cm}$

Two Vertical type shading devices of length 35 cm is suggested.

The spacing between the Horizontal members is given by $0.54 P$, where p is the length of the projection.

For horizontal member: $P = 140/0.54$

$P = 259 \text{ cm}$

Four Horizontal type shading device of length 65 cm is suggested.

Window Type 2:

By Table 10, $V(B = 60 \text{ degree})$ and $H(B=30 \text{ degree})$.

The spacing between the Vertical members is given by $1.46 P$, where p is the length of the projection.

For vertical member : $P = 100/1.46$

$P = 68.5 \text{ cm}$

Two Vertical type shading devices of length 35 cm is suggested.

The spacing between the Horizontal members is given by $0.85 P$, where p is the length of the projection.

For horizontal member: $P = 230/0.85$

$P = 271 \text{ cm}$

Five Horizontal type shading device of length 54 cm is suggested.

WEST FACADE:

Window type 1: (1m x 2.3m)

Combination Type of Shading device:

Window Type 1:

By Table 10, $V(B = 60 \text{ degree})$ and $H(B=30 \text{ degree})$.

The spacing between the Vertical members is given by $1.46 P$, where p is the length of the projection.

For vertical member : $P = 100/1.46$

$P = 68.5 \text{ cm}$

Two Vertical type shading devices of length 35 cm is suggested.

The spacing between the Horizontal members is given by $0.85 P$, where p is the length of the projection.

For horizontal member: $P = 140/0.85$

$P = 271 \text{ cm}$

Five Horizontal type shading device of length 54 cm is suggested.

6.5 DESIGN OF SHADING ELEMENTS

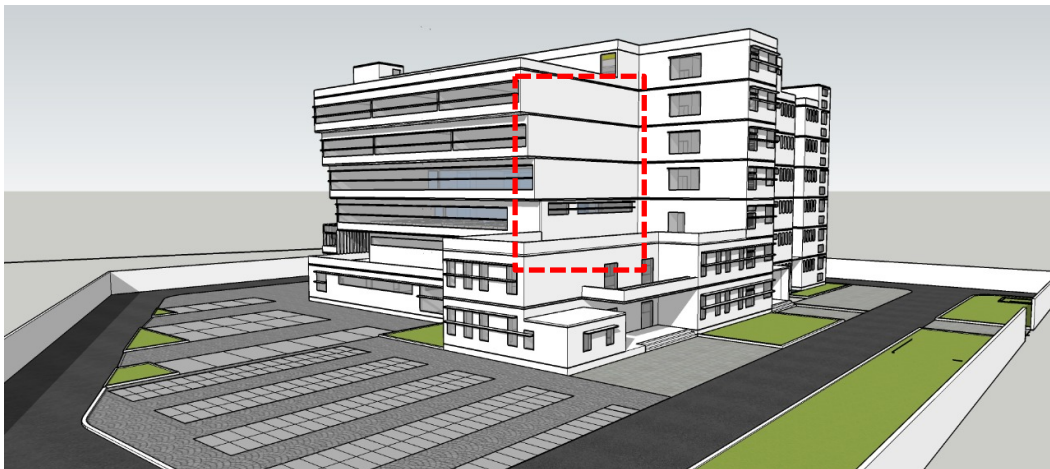


Fig 6.13 South-east View

The East and West wall of the reading spaces should be shaded in order to reduce the heat gain in the indoor.

For the same iterations of shading elements are made.

6.5.1 JAALI-DESIGN ITERATIONS

Nuvocotta brand terracotta Jaali blocks are chosen for the shading of East and West Walls of Reading space. The performance of the selected designs are analysed

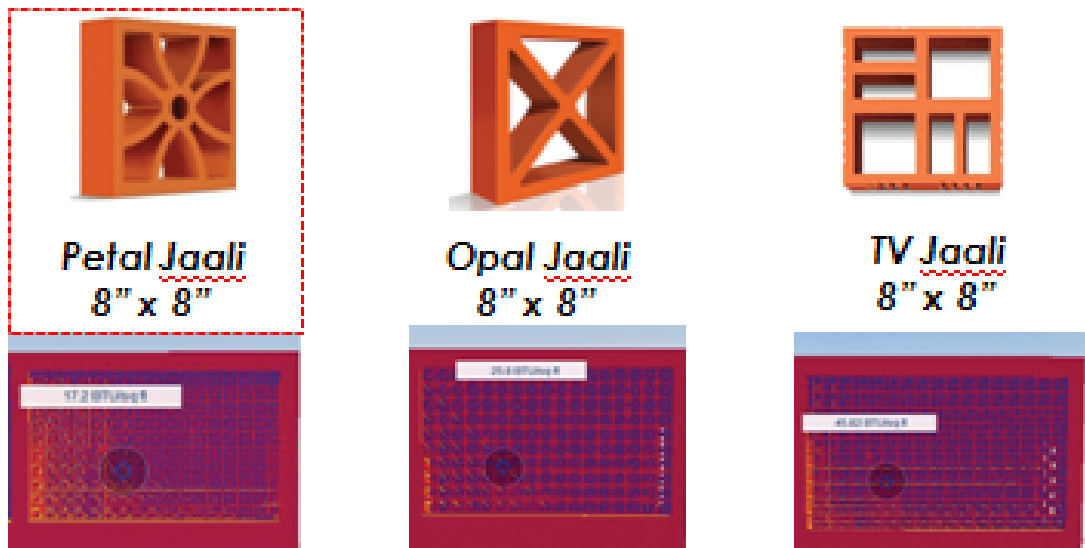


Fig 6.14 Jali block Iterations

Table 6.1 Jali block Iterations

ITERATION	JAALI TYPE	OPENING PERCENTAGE	SOLAR RADIATION
1	Petal Jali	48.75%	17.12 BTU/sq ft
2	Opal Jali	48%	20.85 BTU/sq ft
3	Tv Jali	54%	45.8 BTU/sq ft

From the iterations done it is concluded that the Petal Jali model has achieved maximum reduction in the radiation.

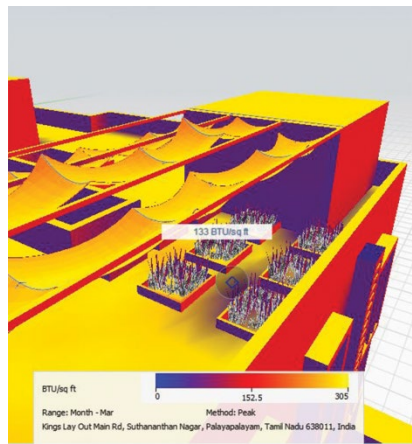


Fig 6.15 Awning design

Retractable Vinyl Awning is used for shading the Balconies.

The Balconies are occasionally used so Temporary shading is needed.

The terrace receives the highest amount of solar radiation of 286 BTU/sq.ft which can be reduced to 133 BTU/sq.ft through planters and awning.

Table 6.2 Jali screen for West Wall

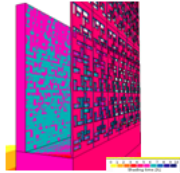
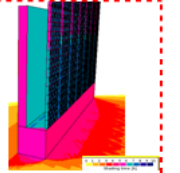
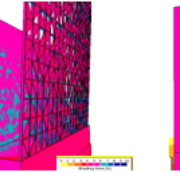
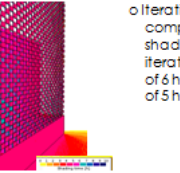
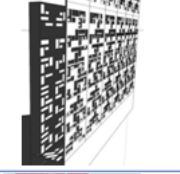
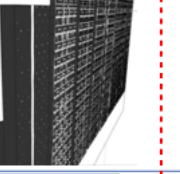
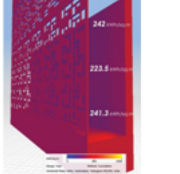
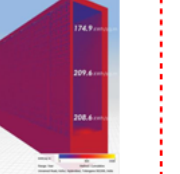
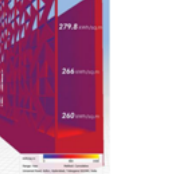
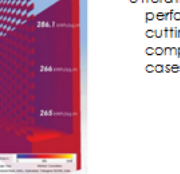
	ITERATION 1	ITERATION 2	ITERATION 3	ITERARION 4	INFERENCE
SHADOW HOURS					o Iteration 2 give complete 6 hours of shading, while other iteration gives maximum of 6 hours and minimum of 5 hours of shading
DAYLIGHT AND SHADE					o Iteration 1, 3 and 4 gives maximum of daylight penetration through the jali,
RADIATION LEVELS					o Iteration 2 seems to perform better in cutting of radiation compared to all other cases.

Table 6.3 Jali screen for East Wall

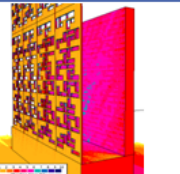
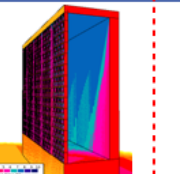
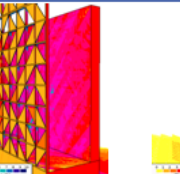
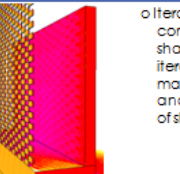
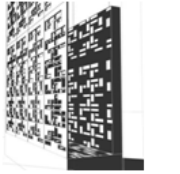
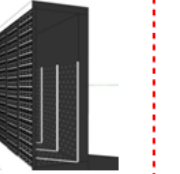
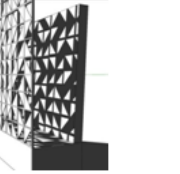
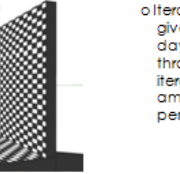
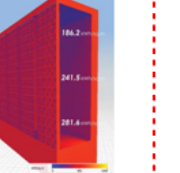
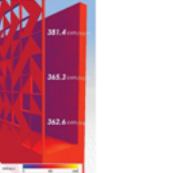
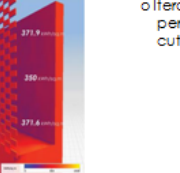
	ITERATION 1	ITERATION 2	ITERATION 3	ITERARION 4	INFERENCE
SHADOW HOURS					o Iteration 2 give complete 6 hours of shading, while other iteration gives maximum of 5 hours and minimum of 4 hours of shading
DAYLIGHT AND SHADE					o Iteration 1, 3 and 4 gives maximum of daylight penetration through the jali, while iteration 2 reduces the amount the daylight penetration
RADIATION LEVELS					o Iteration 2 seems to perform better in cutting of radiation.

Table 6.4 Material Study

COMPONENT	MATERIAL	IMAGE	PROPERTIES	REFERENCE	ADVANTAGES	AVAILABILITY
Wall	Fly ash Bricks		Thermal Conductivity- 0.639 W/m.K		- The raw materials contains about 70% power plant waste. - Good Thermal insulation-Lower energy cost. - Good sound insulation-low noise - Requires very less water in construction. - Requires less mortar during construction-economical. - Production requires no fossil fuel-no greenhouse gas emission. - High compressive strength (9-10 N/mm²)-less wastage. - Thermal conductivity of fly ash bricks is 0.90-1.05 W/mK.	Ponmani Flyash Bricks, Anna Nagar, Madurai Leading Manufacturers of Fly ash Bricks in Madurai
Wall	AAC Blocks		Thermal Conductivity- 0.16-0.18 W/m.K	https://www.civilconcept.com/aac-blocks-specifications/	- AAC block is eco-friendly. - AAC wall has an excellent Sound Proof and Thermal insulation property - AAC shows excellent resistance to the earthquake forces and Fire resistance - Being light weight AAC drastically reduces the dead weight of the building, resulting in the reduction in steel (up to 27%) and cement (up to 20%) structural cost savings.	KM Agencies AAC Block manufacturer in Madurai, Tamil Nadu
Wall Insulation	XPS Board		Conductivity- 0.029-0.032 W/m.K	The Effectiveness of Thermal Insulation in Different Types of Buildings in Hot Climates- MOHAMMAD S. AL-HOMOUD	- Low coefficient of heat transfer compared to other insulations. - It acts as an excellent soundproofing material. - A dense, continuous air barrier for effective insulation properties with high R-value. - XPS is highly efficient at this, and can help reduce the amount of energy needed to maintain temperatures in buildings. - XPS is very environmentally friendly. - XPS can be reduce, reuse, and recycle.	INSUboard Sivans XPS Insulation Supplier Madurai

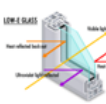
COMPONENT	MATERIAL	IMAGE	PROPERTIES	REFERENCE	ADVANTAGES	AVAILABILITY
Roof	Green Roof			Thermal Performance Evaluation of Green Roofs in Warm Humid Climates: A Case of Residential Buildings in Madurai, India Madhumathi.A, Radhakrishnan and Shanthipriya.R	- Cool roofs appear more desirable, green roofs performance are associated with physical process like evapo-transpiration and shading that contributes fairly well for the energy efficiency of buildings and urban heat island mitigation issues. - Roof top greenery design adverse economic and social concerns as well as environmental aspects of sustainability.	
Outdoor Roofing	Polycarbonate sheet				- It is a light weight and a durable material for outdoor. - Resistant to flame and do not produce toxic gases on fire. - Blocks 93% of UV radiation and allows daylight.	Saraswathi Glasses Saint Gobain, Deales.
Window	Double Low E Glass		U value-1.92 VLT0.75 SHGC-0.30	Reference: Influence of Glazing types on the indoor thermal performance of Tropical Buildings-AI tamimi nedhal and Abdultawab Gahtan	Low E coatings are designed to reduce Heat transfer caused by the long wave radiation. They have emissivity ranging from 0.35 to as low as 0.04, which means 65% to 95% of long wave radiation is reflected back.	
Flooring	Polished concrete				Polished concrete not only utilizes existing concrete surfaces to eliminate the need for additional materials such as coverings/coatings and move toward sustainable building; it also typically contains no volatile organic compounds (VOCs), making it friendly for any U.S. Green Building Council LEED project. The reflective properties of a polished concrete floor improves ambient lighting	

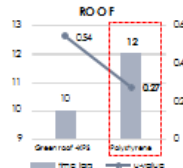
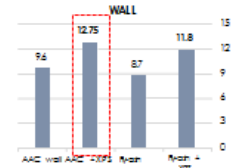
Table 6.5 Water fixtures

PRODUCT CATEGORY	PRODUCT DETAIL	PRODUCT IMAGE	RATING	WATER USAGE OF SELECTED FIXTURES	WATER USAGE OF CONVENTIONAL FIXTURES
Faucet	Hindware CONTESSA Pillar Cock Body		WEP-3 Star rated	3.97 litres per minute (52.17% less consumption than conventional)	8.3 litres per minute
Urinal	Eco 365 Falcon Waterfree Urinals		Member of IGBC	0% Water Usage and Odour free (100% less consumption than conventional)	3.78 litres per flush
Water Closet	2018 Cruise EWC P or S Concealed		WEP-3 Star Rated	3 litres/flush (75% less consumption than conventional)	12 litres/flush

Table 6.6 Material comparison Table

Base case - Brick wall

Materials	Thickness	Time lag
Cement plaster	12.5mm	0.3 hrs
Mud Brick	230mm	5.9 hrs
Cement plaster	12.5mm	0.3 hrs
Total	255mm	6.5 hrs



Iteration 1 - AAC wall

Materials	Thickness	Time lag
Cement plaster	12.5mm	0.3 hrs
AAC block	200mm	9 hrs
Cement plaster	12.5mm	0.3 hrs
Total	225mm	9.6 hrs

Iteration 3 - Fly-ash brick with XPS board

Materials	Thickness	Time lag
Cement plaster	12.5mm	0.3 hrs
Fly-ash Brick	200mm	8.1 hrs
Cement plaster	12.5mm	0.3 hrs
Total	220mm	8.7 hrs

Thermal transmittance of green roof (U_g)
 Total thermal resistance, $R_t = 0.17 + 0.04 + 1.65 = 1.86 \text{ m}^2\text{K/W}$
 Thermal transmittance, $U_{\text{roof}} = 1/R_t = 0.5376 \text{ W/m}^2\text{K}$

Iteration 2 - AAC block with XPS board

Materials	Thickness	Time lag
Cement plaster	12.5mm	0.3 hrs
AAC block	200mm	9 hrs
Adhesive	10mm	0.15 hrs
XPS board	50mm	3 hrs
Cement plaster	12.5mm	0.3 hrs
Total	285mm	12.75 hrs

Iteration 4 - Fly-ash brick with XPS board

Materials	Thickness	Time lag
Cement plaster	12.5mm	0.3 hrs
Fly-ash Brick	200mm	8.1 hrs
Adhesive	10mm	0.15 hrs
XPS board	50mm	3 hrs
Cement plaster	12.5mm	0.3 hrs
Total	285mm	11.8 hrs

Thermal transmittance of insulated roof (U_g)
 Total thermal resistance, $R_t = 0.17 + 0.04 + 1.72 = 1.931 \text{ m}^2\text{K/W}$
 Thermal transmittance, $U_{\text{roof}} = 1/R_t = 0.2682 \text{ W/m}^2\text{K}$

Iteration 1 - Green roof

Material layer	Thickness, t (m)	Thermal conductivity, k (W/mK)	Thermal resistance of material, R=t/k (m²K/W)
Growing medium	0.15	0.73	0.205
Filtration layer	0.015	0.06	0.25
Drainage layer	0.008	0.08	0.1
EPS board	0.03	0.035	0.8571
Waterproof layer	0.003	0.17	0.017
Cinder concrete	0.05	0.730	0.068
RCC slab	0.15	1.58	0.095
Inner cement plaster	0.01	0.721	0.013
Sum of all material thermal resistance			1.65
Time lag			10 hrs

Iteration 2 - Polystyrene roof

Material layer	Thickness, t (m)	Thermal conductivity, k (W/mK)	Thermal resistance of material, R=t/k (m²K/W)
Cooling tile	0.05	0.798	0.063
Cinder concrete	0.05	0.730	0.068
RCC slab	0.1	1.58	0.063
Polystyrene	0.05	0.038	1.58
Inner cement plaster	0.01	0.721	0.014
Sum of all material thermal resistance			1.721
Time lag			12 hrs

6.6 DAYLIGHT ANALYSIS:

Table 6.7 Daylight analysis-Ground floor

Key Plan	Point in time Illuminance 0 lux 200 lux 500 lux 1000 lux	Useful Daylighting Illuminance 0 lux 1000 lux	Daylight Autonomy 0% 100%	Spatial Daylight Autonomy 0% 100%	Annual Solar Exposure 0 hr 250 hr
Competitive Exam	 307 lux	 UDI-88.76%	 DA-75.12%	 sDA-77.54%	 ASE-0.00%
Own book Reading	 332 lux	 UDI-98.92%	 DA-78.32%	 sDA-88.27%	 ASE-3.09%
Network and Security	 350 lux	 UDI-97.98%	 DA-96.70%	 sDA-100%	 ASE-0.00%

Table 6.8 Daylight analysis-Ground float-2

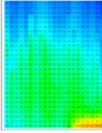
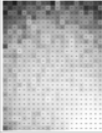
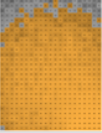
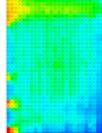
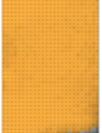
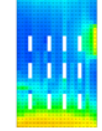
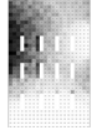
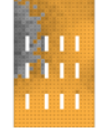
Key Plan	Point in time Illuminance	Useful Daylighting Illuminance	Daylight Autonomy	Spatial Daylight Autonomy	Annual Solar Exposure
Multifunction (North)	 350.8 lux	 UDI-99.46%	 DA-75.52%	 sDA-86.95%	 ASE-0.00%
Multifunction (South)	 389.7 lux	 UDI-98.67%	 DA-93.86%	 sDA-99.09%	 ASE-0.23%
Differently-Abled	 328 lux	 UDI-98.66%	 DA-76.38%	 sDA-83.99%	 ASE-0.87%

Table 6.9 Daylight analysis-First float

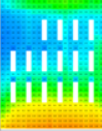
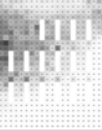
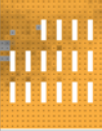
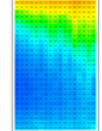
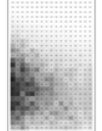
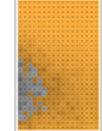
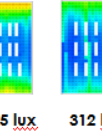
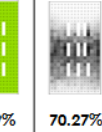
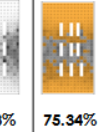
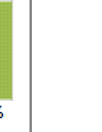
Key Plan	Point in time Illuminance	Useful Daylighting Illuminance	Daylight Autonomy	Spatial Daylight Autonomy	Annual Solar Exposure
Children Section	 489 lux	 UDI-98.26%	 DA-86.10 %	 sDA-97.14%	 ASE-6.5%
Performance Centre	 365.9 lux	 UDI-99.13%	 DA-79.64%	 sDA-90.20%	 ASE-0.00%
Periodicals and Journals	 365 lux	 99.09%	 70.27%	 75.34%	 0.00%
	 312 lux	 99.49%	 81.98%	 92.29%	 0.00%

Table 6.10 Daylight analysis-Second float

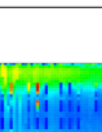
Key Plan	Point in time Illuminance	Useful Daylighting Illuminance	Daylight Autonomy	Spatial Daylight Autonomy	Annual Solar Exposure
Tamil Book Section (North)	 313 lux	 UDI-86.65%	 DA-83.38%	 sDA-87.71%	 ASE-1.57%
Tamil Book Section (South)	 346lux	 UDI-88.51%	 DA-80.21%	 sDA-86.33%	 ASE-3.58%

Table 6.11 Daylight analysis-Third floor

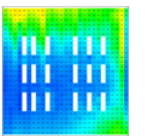
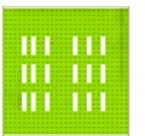
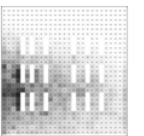
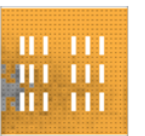
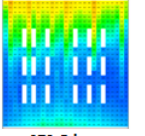
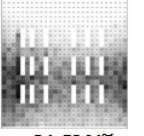
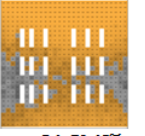
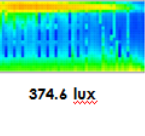
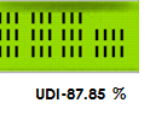
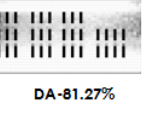
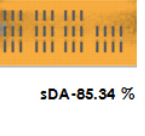
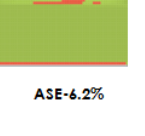
Key Plan	Point in time Illuminance	Useful Daylighting Illuminance	Daylight Autonomy	Spatial Daylight Autonomy	Annual Solar Exposure
English Book Section (North)	 311.3 lux	 UDI-98.65%	 DA-84.95%	 sDA-95.59%	 ASE-0.00%
Archives	 370.5 lux	 UDI-98.36%	 DA-75.04%	 sDA-79.45%	 ASE-0.00%
English Book Section (South)	 374.6 lux	 UDI-87.85 %	 DA-81.27%	 sDA-85.34 %	 ASE-6.2%

Table 6.12 Daylight analysis-Fourth floor

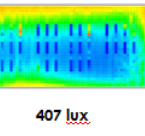
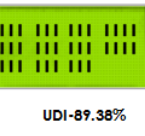
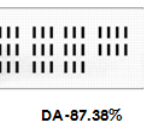
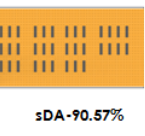
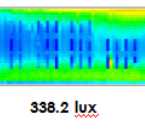
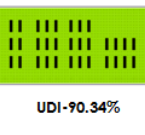
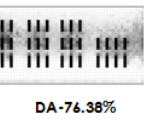
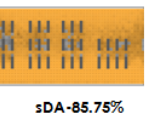
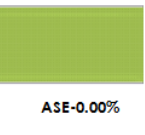
Key Plan	Point in time Illuminance	Useful Daylighting Illuminance	Daylight Autonomy	Spatial Daylight Autonomy	Annual Solar Exposure
Science Section (North)	 407 lux	 UDI-89.38%	 DA-87.38%	 sDA-90.57%	 ASE-0.00%
Economics Section (South)	 338.2 lux	 UDI-90.34%	 DA-76.38%	 sDA-85.75%	 ASE-0.00%

Table 6.13 Daylight analysis-Fifth floor

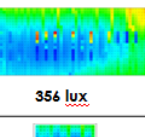
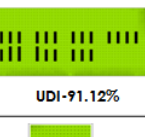
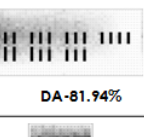
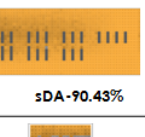
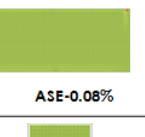
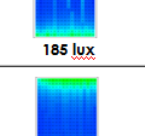
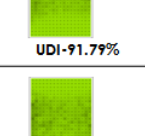
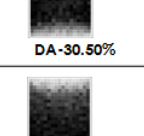
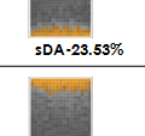
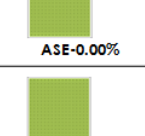
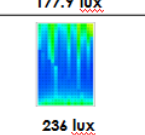
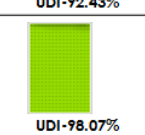
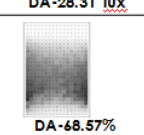
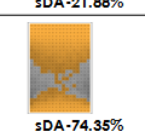
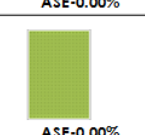
Key Plan	Point in time Illuminance	Useful Daylighting Illuminance	Daylight Autonomy	Spatial Daylight Autonomy	Annual Solar Exposure
Rare Book Section	 356 lux	 UDI-91.12%	 DA-81.94%	 sDA-90.43%	 ASE-0.08%
Microfiche Room	 185 lux	 UDI-91.79%	 DA-30.50%	 sDA-23.53%	 ASE-0.00%
Digitalisation Chamber	 177.9 lux	 UDI-92.43%	 DA-28.31 lux	 sDA-21.88%	 ASE-0.00%
Digital Library	 236 lux	 UDI-98.07%	 DA-68.57%	 sDA-74.35%	 ASE-0.00%

Table 6.14 Daylight analysis-Sixth float

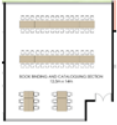
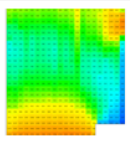
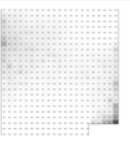
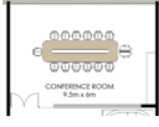
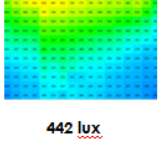
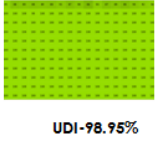
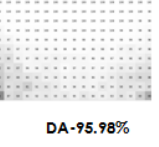
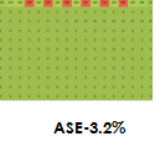
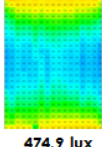
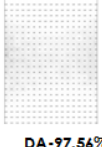
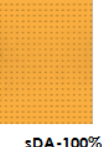
Key Plan	Point in time Illuminance	Useful Daylighting Illuminance	Daylight Autonomy	Spatial Daylight Autonomy	Annual Solar Exposure
Cataloguing and Binding 	 634 lux	 UDI-98.94%	 DA-96.39%	 sDA-99.79%	 ASE-2.54%
Board Room 	 442 lux	 UDI-98.95%	 DA-95.98%	 sDA-100%	 ASE-3.2%
Chief Librarian 	 474.9 lux	 UDI-98.86%	 DA-97.56%	 sDA-100%	 ASE-3.84%

Table 6.15 Comparative analysis-1

Space	Glazing	Shading	Daylight Autonomy (DA)		Spatial Daylight Autonomy (sda)		Annual Solar Exposure (ASE)		Average Illuminance	
			Target %	Achieved	Target %	Achieved	Maximum	Achieved	Standard	Achieved
Competitive Exam Section	DG-Low E VLT-0.73 SHGC-0.54	Vertical Member 0.5m	75%	75.12%	75%	77.54%	5%	0.00 %	200-300-500 lux	307 lux
Ownbook Reading Section	DG-Low E VLT-0.73 SHGC-0.54	Vertical Member 0.5m	75%	78.32%	75%	88.27%	5%	3.09%	200-300-500 lux	332 lux
Networkand Security	DG-Low E VLT-0.73 SHGC-0.54	Vertical Member 0.5m	75%	96.70%	75%	100%	5%	0.00%	200-300-500 lux	350 lux
Multi-Function Room	DG-Low E VLT-0.73 SHGC-0.54	Vertical Member 0.5m	75%	75.52%	75%	86.95%	5%	0.00%	200-300-500 lux	350.8 lux
Multi-Function Room	DG-Low E VLT-0.73 SHGC-0.54	Horizontal Member 0.42m	75%	93.86%	75%	99.09 %	5%	0.23%	300-500-750 lux	389.7 lux
Differently-Abled Section	DG-Low E VLT-0.73 SHGC-0.54	Horizontal Member 0.42m	75%	76.38%	75%	83.99%	5%	0.87%	300-500-750 lux	328 lux
Children Section	DG-Low E VLT-0.73 SHGC-0.54	Horizontal Member 0.42m	75%	86.10%	75%	97.14%	5%	6.5%	200-300-500 lux	489 lux
Performance Centre	DG-Low E VLT-0.73 SHGC-0.54	Vertical Member 0.5m	75%	79.64%	75%	90.20%	5%	0.00%	300-500-750 lux	365.9 lux

Table 6.16 Comparative analysis-2

Space	Glazing	Shading	Daylight Autonomy (DA)		Spatial Daylight Autonomy (Sda)		Annual Solar Exposure (ASE)		Average Illuminance	
			Target %	Achieved	Target %	Achieved	Maximum	Achieved	Standard	Achieved
Periodicals and Journals	DG-Low E VLT-0.73 SHGC-0.54	Vertical Member 0.5m	75%	81.98%	75%	92.29%	10%	0.00%	200-300-500 lux	365 lux
Tamil Book Section North	DG-Low E VLT-0.73 SHGC-0.54	Vertical Member 0.5m	75%	83.38%	75%	87.71%	10%	1.57%	200-300-500 lux	313 lux
Tamil Book Section South	DG-Low E VLT-0.73 SHGC-0.54	Horizontal Member 0.42m	75%	80.21%	75%	86.33%	10%	3.58%	200-300-500 lux	346 lux
English Book Section North	DG-Low E VLT-0.73 SHGC-0.54	Vertical Member 0.5m	75%	84.95%	75%	95.59%	10%	0.0%	200-300-500 lux	311.3 lux
Archives	DG-Low E VLT-0.73 SHGC-0.54	Vertical Member 0.5m	75%	75.04%	75%	79.45%	10%	0.0%	200-300-500 lux	370.5 lux
English Book Section South	DG-Low E VLT-0.73 SHGC-0.54	Horizontal Member 0.42m	75%	81.27%	75%	85.34%	10%	6.2%	200-300-500 lux	374.6 lux
Science Section North	DG-Low E VLT-0.73 SHGC-0.54	Vertical Member 0.5m	75%	87.38%	75%	90.57%	10%	0.00%	200-300-500 lux	407 lux
Economics Section South	DG-Low E VLT-0.73 SHGC-0.54	Horizontal Member 0.42m	75%	76.38%	75%	85.75%	10%	0.00%	200-300-500 lux	338.2 lux

Table 6.17 Comparative analysis-3

Space	Glazing	Shading	Daylight Autonomy (DA)		Spatial Daylight Autonomy (Sda)		Annual Solar Exposure (ASE)		Average Illuminance	
			Target %	Achieved	Target %	Achieved	Maximum	Achieved	Standard	Achieved
Rare Book Section	DG-Low E VLT-0.73 SHGC-0.54	Vertical Member 0.5m	75%	81.94%	75%	90.43%	10%	0.08%	200-300-500 lux	356 lux
Microfiche Room	DG-Bronze VLT-0.45 SHGC-0.39	Horizontal Member 0.42m	75%	30.50%	75%	23.53%	10%	0.00%	100-150-200 lux	185 lux
Digitalisation Chamber	DG-Bronze VLT-0.45 SHGC-0.39	Horizontal Member 0.42m	75%	28.31%	75%	21.88%	10%	0.00%	100-150-200 lux	177.9 lux
Digital Library	DG-Bronze VLT-0.45 SHGC-0.39	Horizontal Member 0.42m	75%	68.57%	75%	74.35%	10%	0.00%	200-300-500 lux	236 lux
Cataloguing	DG-Low E VLT-0.73 SHGC-0.54	Vertical Member 0.5m	75%	96.39%	75%	99.79%	10%	2.54%	200-300-500 lux	634 lux
Binding	DG-Low E VLT-0.73 SHGC-0.54	Vertical Member 0.5m	75%	96.39%	75%	99.79%	10%	3.2%	200-300-500 lux	634 lux
Board Room	DG-Low E VLT-0.73 SHGC-0.54	Vertical Member 0.5m	75%	95.98%	75%	100%	10%	3.2%	200-300-500 lux	442 lux
Chief Librarian	DG-Low E VLT-0.73 SHGC-0.54	Vertical Member 0.5m	75%	97.56%	75%	100%	10%	3.84%	300-500-750 lux	474.9 lux

6.7 CONCLUSION

All the regularly occupied reading spaces achieve Useful Daylight Illuminance of more 90% throughout the day.(GRIHA complied).

Daylight Autonomy of more than 75% is achieved in all regularly occupied Reading Spaces.

It meets the requirement of LEED for achieving the maximum points (3 points) for daylight performance.

The Annual Solar exposure does not exceed 10% in all the spaces thus there is no potential for disability and discomfort glare.

It makes the building comply with the WELL Building Standards.

Spatial Daylight Autonomy of more than 75% is achieved in all regularly occupied reading spaces.

It meets the requirement of IGBC for attaining the maximum points (4 points) for daylight performance.

Point in time illuminance for September 21st 12 noon period was done and the average illuminance was found to be between 300-400 lux.

This makes it comply with the IGBC requirement for daylight performance.

The luminous ratio does not exceed 1:20 in all spaces thus providing uniform lighting in the interior. Sensation of glare is avoided.

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