

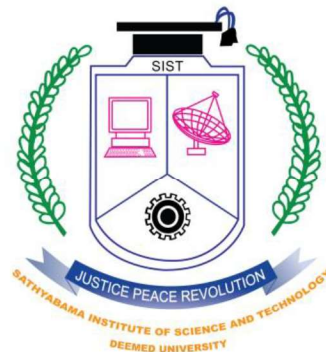
OPTIMIZATION OF DAYLIGHT IN SUBTERRANEAN STRUCTURES: PROPOSAL FOR ARIYALUR FOSSIL MUSEUM

A Thesis

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

by

B SELVA PRIYADHARSHAN (39890016)



**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

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BONAFIDE CERTIFICATE

This is to certify that this Report is the bonafide work of
B SELVA PRIYADHARSHAN (39890016) who carried out the Thesis entitled “**OPTIMIZATION OF DAYLIGHT
IN SUBTERRANEAN STRUCTURES: PROPOSAL FOR ARİYALUR FOSSIL MUSEUM**” under our
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DECLARATION

I **B SELVA PRIYADHARSHAN** hereby declare that the Thesis Report entitled **“OPTIMIZATION OF DAYLIGHT IN SUBTERRANEAN STRUCTURES: PROPOSAL FOR ARIYALUR FOSSIL MUSEUM”** done by me under the guidance of **Ar. SHOBANA SUBRAMANIAN** (Internal) and **Ar. BALA MURUGAN** (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:

PLACE:

SIGNATURE OF THE CANDIDATE

ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to Board of Management of **SATHYABAMA** for their kind encouragement in doing this Thesis project and for completing it successfully. I am grateful to them.

I convey my thanks to **Dr. Devyani Gangopadhyay, Dean and Head of the department, Dept. of Architecture, School of Building and Environment**, for providing me necessary support and details at the right time during the progressive reviews.

My special thanks to **Dr. Suresh Kuppusamy**, our Design chair and **Ar.Bala murugan**, (External guide) and **Ar. Sheetal Amraotkar** (Thesis Coordinator) for their valuable comments and guidance during the project work.

I would like to express my sincere and deep sense of gratitude to my Project Guide **Ar. Shobana subramanian** for her valuable guidance, suggestions and constant encouragement which paved way for the successful completion of my project work.

I wish to express my thanks to all Teaching and Non-teaching staff members of the Department of Architecture who were helpful in many ways for the completion of this Thesis.

ABSTRACT

The underground structure forms an integral constituent of infrastructure which is mostly used for various purposes. The main requirement in the underground space development is the need of natural day light, hence the research will focus on optimizing the use of daylight in underground by incorporating the combination of structural elements and construction technologies. The goal is to develop an underground platform in Ariyalur fossil museum and to provide daylight by the detailed study of subterranean construction techniques which leads to provide a new underground atmosphere. The result would be an attempt to point out the value of using innovative day lighting system in underground which would be referred as a benchmark for such future underground projects.

KEYWORDS: Daylight, underground structures, courtyard, atrium, lux level.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

There are many studies and research prove that our human bodies are literally designed for natural light. It produces vitamin D and improves our metabolism. The natural daylight has many benefits, it is important for human's both physiological and psychological wellbeing. No electric lamp can match that.

In Architecture, daylight plays a major role in improving space quality, occupant's health well-being and also for indoor comfort. One of the most challenging parts in underground space development is receiving daylight. These underground structures form an integral constituent of the infrastructure which is mostly used for various purposes and is usually constructed beneath the surface of the earth. The underground space should have a major purpose or need to be built and in future, the structures maybe used to an unrivalled extend through unique and creative design techniques.

Among many constrains, the use of natural daylight on underground is the major issue. By providing daylight in the underground spaces, many advantages can be clearly identified. Starting with the increase of underground space use, passing by the enhancement of the built environment - by increasing open areas above grade by moving certain undeceived functions below grade and finally discovering different and new environments that have never been explored before. In underground, it has many prospects which provide simulation by connecting people with outside atmosphere and sunlight.

This research proposes an underground platform in Ariyalur fossil museum and provides daylight into the spaces by the detailed study of subterranean construction techniques. This leads to provide a new generation of underground environment.

1.2 AIM

The main goal is to develop an underground platform in Ariyalur underground fossil museum and to provide daylight into the spaces by the detailed study of subterranean construction techniques. This leads to provide a new generation of underground environment.

1.3 RESEARCH QUESTIONS

Why we go for underground structures?

What is the importance of daylight in underground structures?

In what way the museum is going to acquire benefits by the proposal?

What is the average lux level required in underground?

1.4 OBJECTIVES

- To create an underground museum at Ariyalur for ASI (Archaeological survey of India) which is an extension of the fossil museum.
- To develop a natural daylighting system in underground fossil museum, by enhancing the working conditions of it through the combination of construction techniques.
- To provide the knowledge regarding the performance of daylighting systems and strategies.
- To overcome the lack of display counter in the museum.
- To assist fossil preservation in the museum.

1.5 SCOPE OF THE STUDY

In future the demand to build the underground structure may increases, this proposed designed strategies would be referred as a benchmark for such future sustainable projects. It is probable that the proposed design feature can be enhanced in ways by considering the other environmental features in future.

1.6 LIMITATIONS OF THE STUDY

The proposed daylighting system shows that each system has its own advantages and dis-advantages.

- This proposal in future needs to be chosen considering the parameters such as Ventilation, indoor comfort and type of building.
- The retrofit of existing building is only 40-50%

CHAPTER 2 LITERATURE REVIEW

2.1 Study of Passive Methods

There are certain methods which would be used to provide daylight in to the underground structures. Such methods are traditional passive methods and innovative day lighting systems, which are implemented based on the characteristics of the space. The study of passive methods includes Courtyard, Atrium and Top lighting systems.

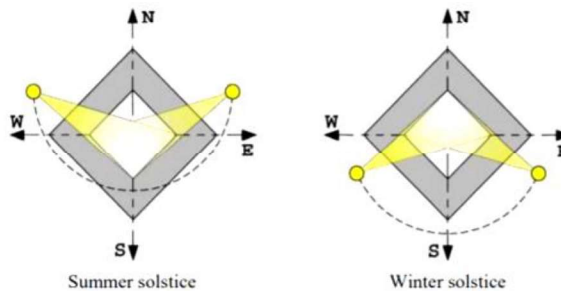


Figure 2.1.1: Summer and winter solstice of 45 degree-oriented courtyard

2.1.1 Courtyard

A courtyard is a space which is open to sky, presents within a building or between the buildings. Several characteristics will be addressed in the day lighting analysis of the courtyard. These characteristics include:

A.Orientation to the Sun

In older cities, with no grid pattern of streets, there is a massive variety of courtyard orientation whereas in newer gridded cities, the streets with courtyards are generally either oriented to the North-South and East-West cardinal points or set at about 45 degrees off the cardinal points. The consequence of 45-degree orientation gives an eventual distribution of sunlight on the facade throughout the year. At summer solstice, morning sun falls on the northeast-facing walls; evening sun falls on the northwest facing walls. At winter solstice, morning sun falls on the southeast-facing walls; evening sun falls on the southwest-facing.

B.Types

There are a number of courtyard types such as two-sided Courtyard, three-sided courtyard and four-sided courtyard are available to optimize daylight into the underground space.

C.Shape and Geometry

If the form of the courtyard can be utterly independent of size and shape of the site, then the designer's first task is to define its proportions: Length, Width, and Height. Usually, one large courtyard is better than two smaller ones. If sun penetration is required into the adjoining spaces, then the court should be designed wider but not too deep.

The design of courtyard proportions will lead to study the courtyard aspect ratio.

$$\text{Aspect Ratio} = \frac{\text{Area of the courtyard floor}}{(\text{Average height of surrounding walls})^2}$$

2.1.2 Atrium

Atria are the central courts and are considered to be part of the building to which they are attached with glazed roof. They allow daylight penetration into the core deep levels. The amount of light available at the base of the atrium depends on the following factors: the atrium orientation to the sun, the shape of the atrium and its geometrical proportions, the transmittance of the atrium roof, the reflectivity of the atrium surfaces and the penetration of daylight into adjoining spaces.

A. Orientation to the Sun

The orientation of the atrium and the openings within its walls are the significant factors which plays a major role in daylight penetration into the floor level spaces. The north-south alignment of atrium may allow daylight penetration into the base of the atrium but not to the spaces adjoining it. An east-west alignment type will allow daylight penetration to the upper floors of the south facing facade but not to the base of the atrium.

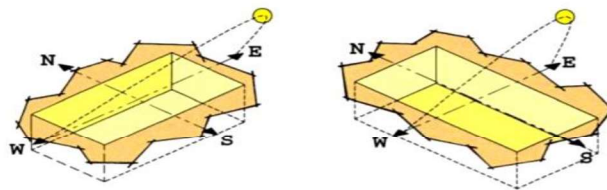


Figure 2.1.2: North-south alignment and East-West alignment atrium types

In general, the best recommended orientation of the atrium openings is the north oriented types whereas the southeast and southwest orientations are considered to be

worst as the sun's angle is low and the intensity of the light is variable which may cause visual problems.

B. Types

There are a number of Atrium types such as two-sided atrium, three-sided atrium, four-sided atrium and Linear-atrium are available to optimize daylight into underground space.

C. Shape and Geometry

The critical proportional relationship in designing an atrium is the ratio of the width of the atrium (W) to the height of the building (H). This ratio is expressed by H/W.

The geometric proportions of an atrium are best described by the combination of two parameters, the Plan Aspect Ratio (PAR), which is the ratio of the atrium width to its length, and the Section Aspect Ratio (SAR) which is the ratio of the atrium height to its width.

For the given width (W), length (L) and height (h) of an atrium the ratios are:

$$\text{PAR} = \text{well width (W)} / \text{well length (L)}$$

$$\text{SAR} = \text{well height (H)} / \text{Well width (W)}$$

As the width of the atrium is increased relatively to its height the daylight penetration in the atrium is improved. As the width of the atrium is decreased relatively to its height, the penetration becomes lower.

2.1.3 Top lighting Systems

Top-lighting concepts are those in which the daylight penetrates an underground space from openings that are located above the ceiling line and usually constitute the part of building roof. Top-lighting perceptions were used in cases where the side-lighting from courts or atria is insufficient.

They can be used to improve the level of penetration from the side lighting apertures.

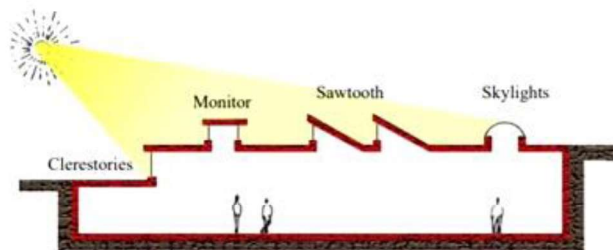


Figure 2.1.3: Top lighting concepts

Top lighting concept offers a better illumination in terms of quality and quantity. As the daylight can be controlled a desired Top lighting could be divided into horizontal and vertical a top-lighting technique which includes skylight, monitors, saw tooth and clerestories. Each of these concepts involves a different architectural treatment of the building form and interior design. Each technique provides a unique lighting character and distribution patterns that differ from all the other lighting concepts.

2.2 STUDY OF ACTIVE METHODS

There are certain innovative active day lighting systems which are used to incorporate daylight into the deep underground levels. Such active methods are Heliostat and Fiber optics day lighting system.

2.2.1 Heliostat Day lighting System

A "Heliostat" is a device consisting of movable mirrors that tracks the sun as it crosses the sky, this constantly reflecting direct sunlight to any desired location within the building by means of other fixed mirrors.

The simplest heliostat devices use a clock mechanism to turn the mirror in synchronization with the rotation of the earth, whereas the advanced active heliostats consist of both primary and secondary a mirror which automatically tracks the sun rays and transmit into the space through solar luminous.

The heliostat main concept is the reflection of direct illuminance into the building by concentrating the received light through collimator which increases the density of arriving sunlight.

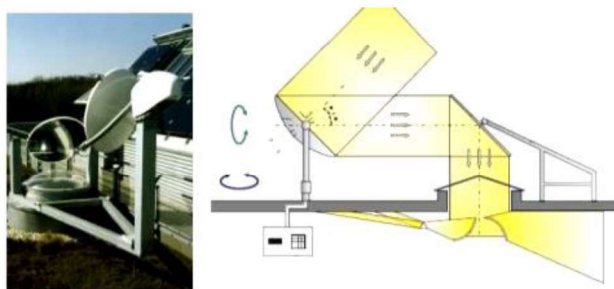


Figure 2.2.1: Mechanism of Heliostat

2.2.2 Fiber Optics Day lighting System

An optical fiber is a thin fiber for transmitting light. Fiber optic lighting systems have the advantage of transmitting light from the light source which is separated from the light output and there is no electricity transported into the fiber. No heat or current, no infrared and no ultraviolet radiation are led through the fiber, only light can pass through. One advantage of the fiber optic lighting system is that it is possible to use it in contact with water, like swimming pools or water fountains with no electricity transported.

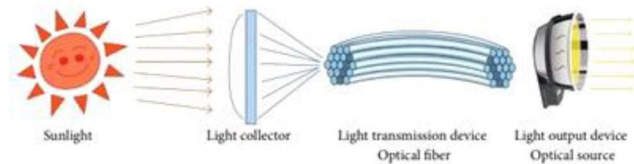


Figure 2.2.2: Mechanism of Fiber Optics Cable

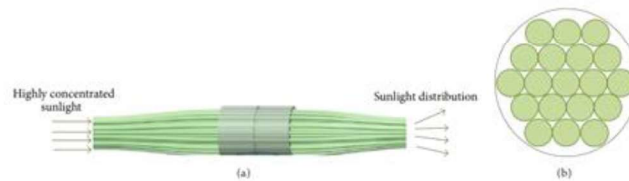


Figure 2.2.3: Sunlight Distribution through Fiber Optics Cable

2.2.3 Sunlight collector System

The SP4-8.2 give each light point give 700-1100 lumen. All values are based on solar illuminance of 100 000 Lux and dependent on the cable length. It helps to save 0.5 million (5L) in Energy cost per year.

SP4 – 8.2



SP4-8.2

LIGHT OUTPUT (lm):
5600 -8800

LIGHT POINTS (Pcs): 8
POWER PRODUCTION (PPD):
400W PER LIGHTPOINT = 400 X 8
= 3200W

SYSTEM EFFICACY:
16,200 WH

Cost: 3,32000 (INR)

Figure 2.2.4: Sun collector system

CHAPTER 3 STUDY OVERVIEW

3.1 AREA OF STUDY

Fossils play a vital role in learning pre historic archaeology and evolution. Ariyalur fossil museum is one of the museums in India and the only fossil museum located in Tamilnadu. It is located in Varanavasi, Ariyalur district of Tamilnadu in India. The district is well known for its rich prehistoric fossils. The museum department is expecting all the development within the area of 10,386.68 square meters (2.5 acres) around the building and the museum also entails a good preservation for the fossils. The proposed underground design helps to attract the people and connect both the excavation site and the museum. Therefore, it will be easier to display all kinds of fossils. The proposed design not only helps in preserving fossils but also help in teaching the younger generation about the prehistory archaeology and progression. Most of the visitors to the museum are from Archaeological students from in and around Tamilnadu and also from keelapalur and Varanavasi district Schools and colleges. The museum also attracts the tourists from worldwide.



Fig: 3.1.1 : Proposed site (Source: Google maps)



Fig. 3.1.2 Photos of the Study area Ariyalur Fossil museum, Tamilnadu.

3.2 METHODOLOGY

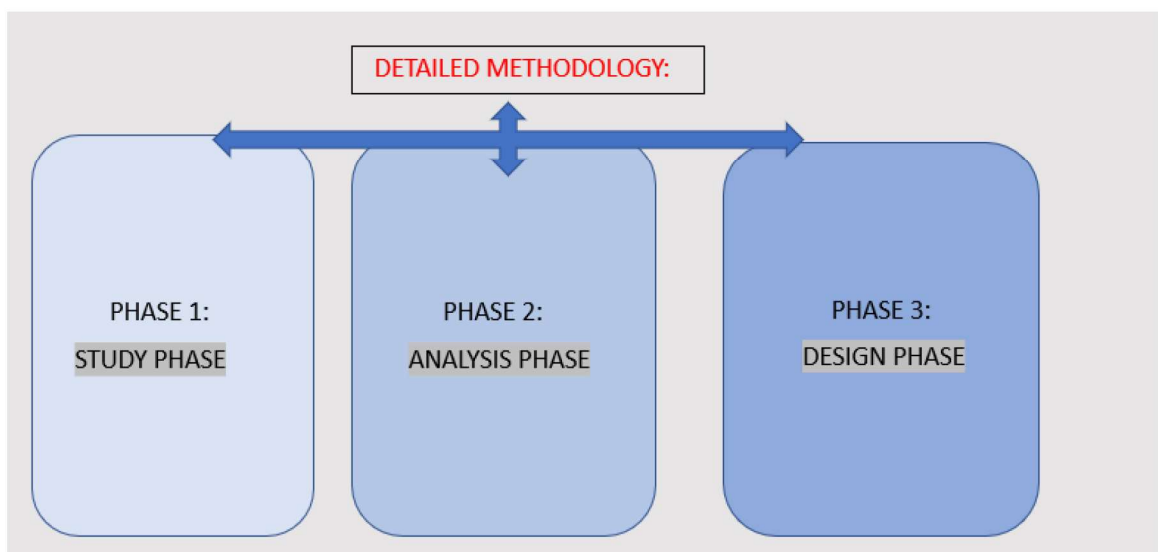


Fig. 3.2.1 Detailed methodology

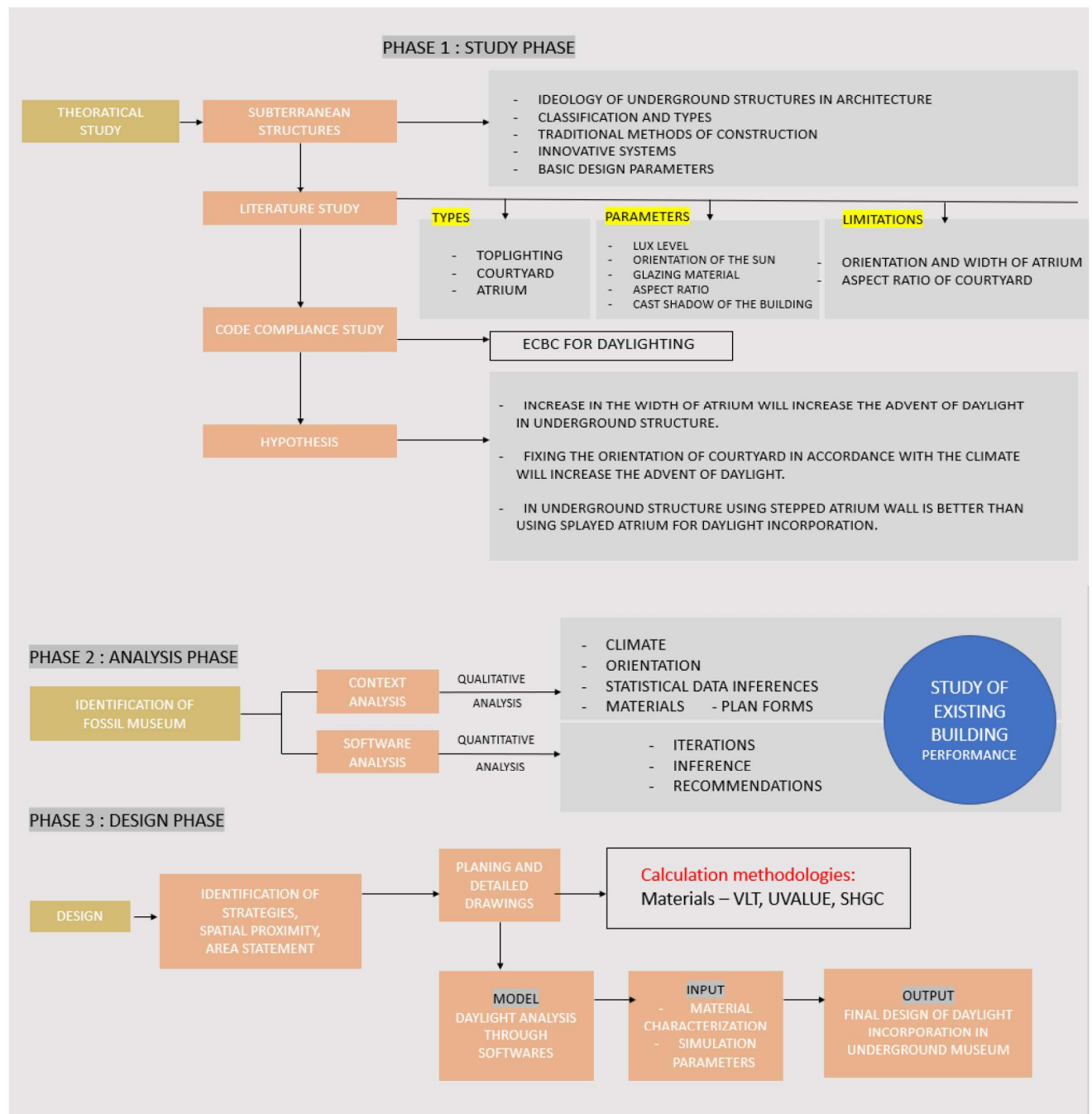


Fig. 3.2.2 Detailed phases

3.3 CLIMATE ANALYSIS

The climate of Ariyalur district is sub-tropical. The average rainfall of the district during Northeast monsoon and Southwest monsoon is 485 mm 357 mm respectively

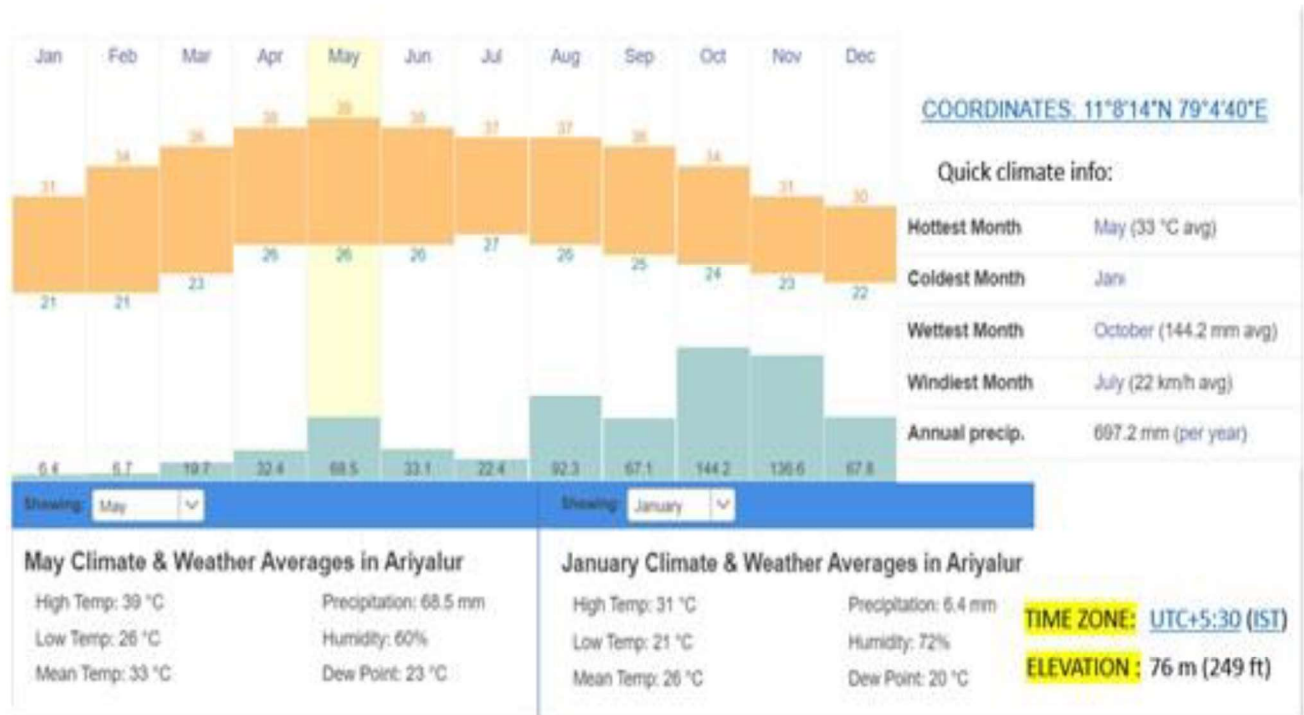


Fig. 3.3.1 Monthly weather averages of Ariyalur.

3.4 CONTEXT ANALYSIS

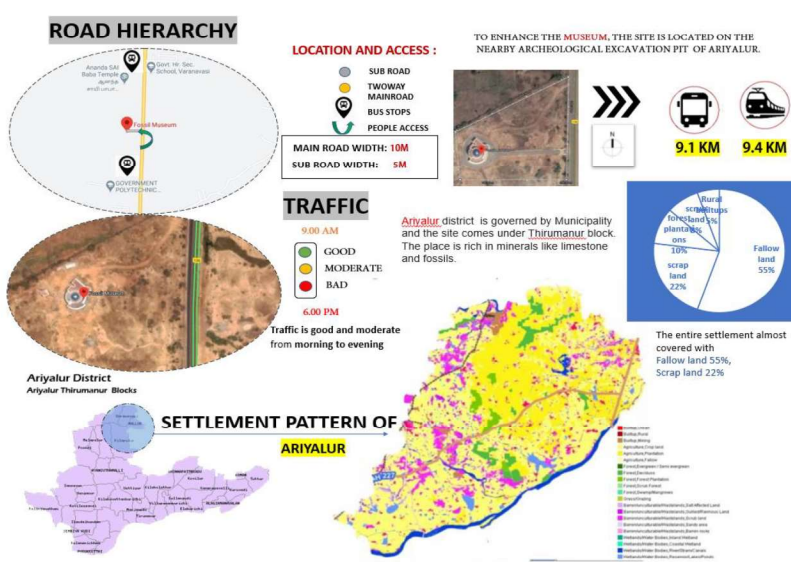
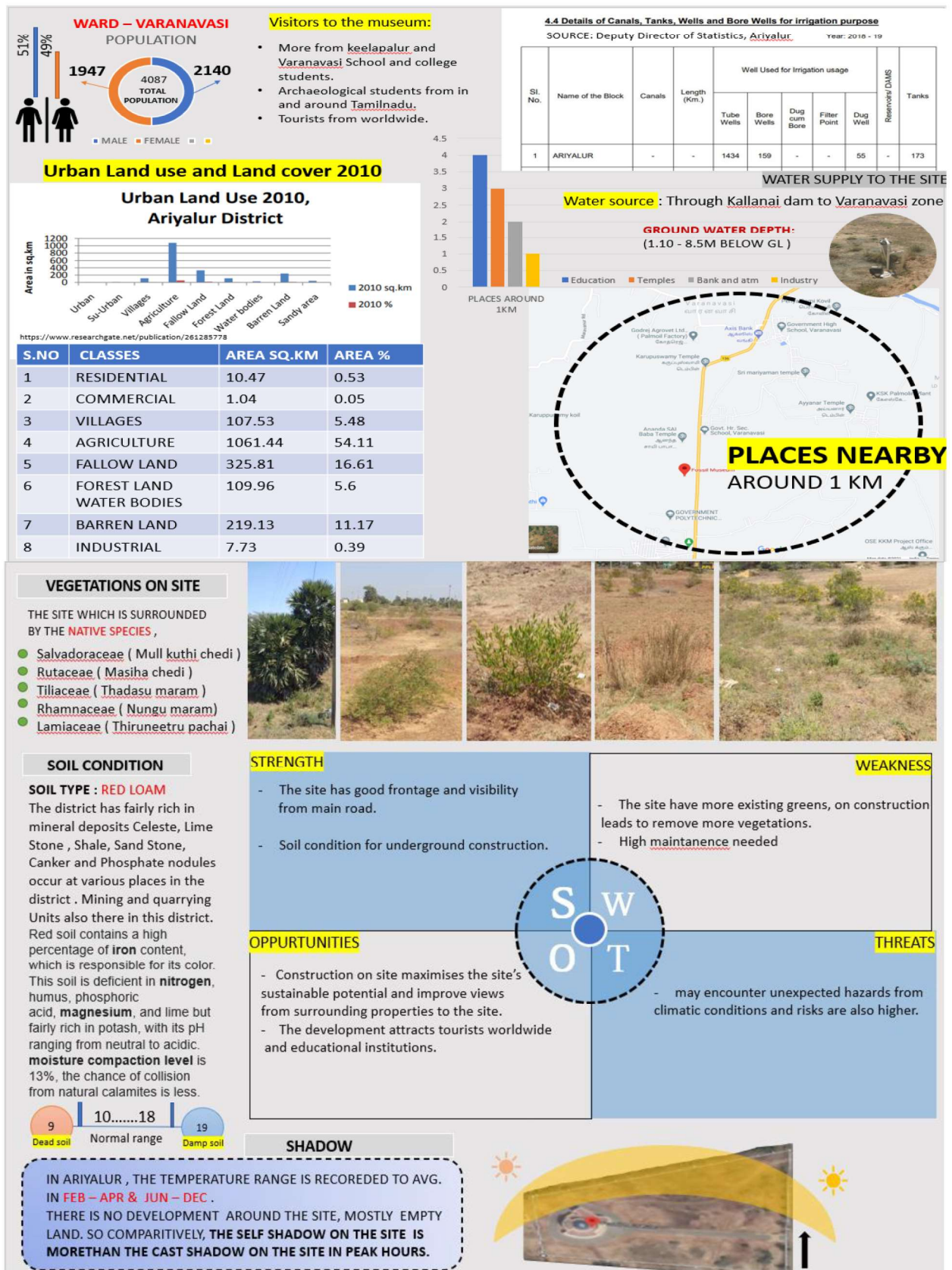
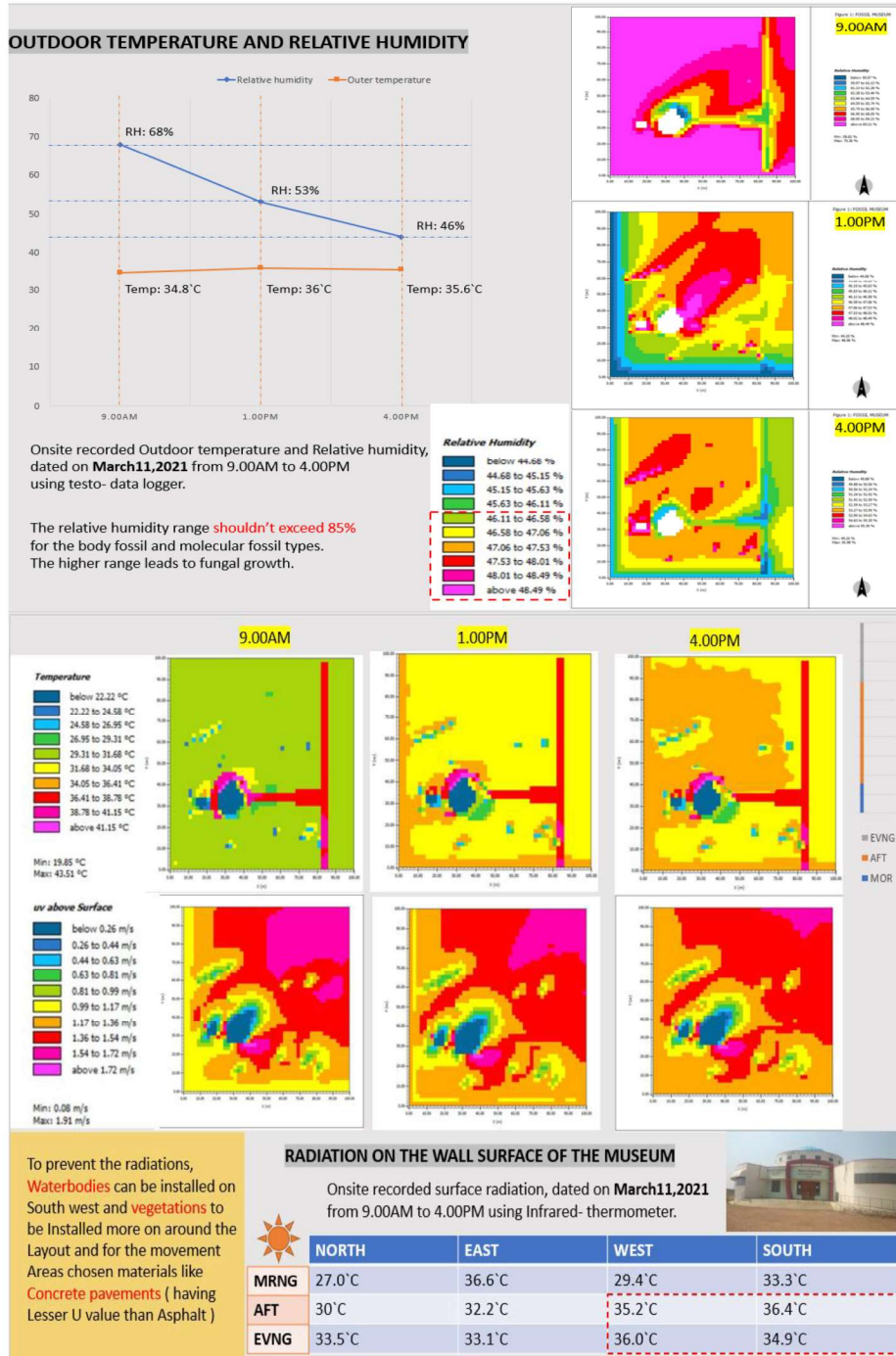


Fig.3.4.1 Site surroundings



CHAPTER 4 RESULTS AND DISCUSSIONS

4.1 SITE OUTDOOR ANALYSIS



4.2 SHADOW ANALYSIS ITERATIONS

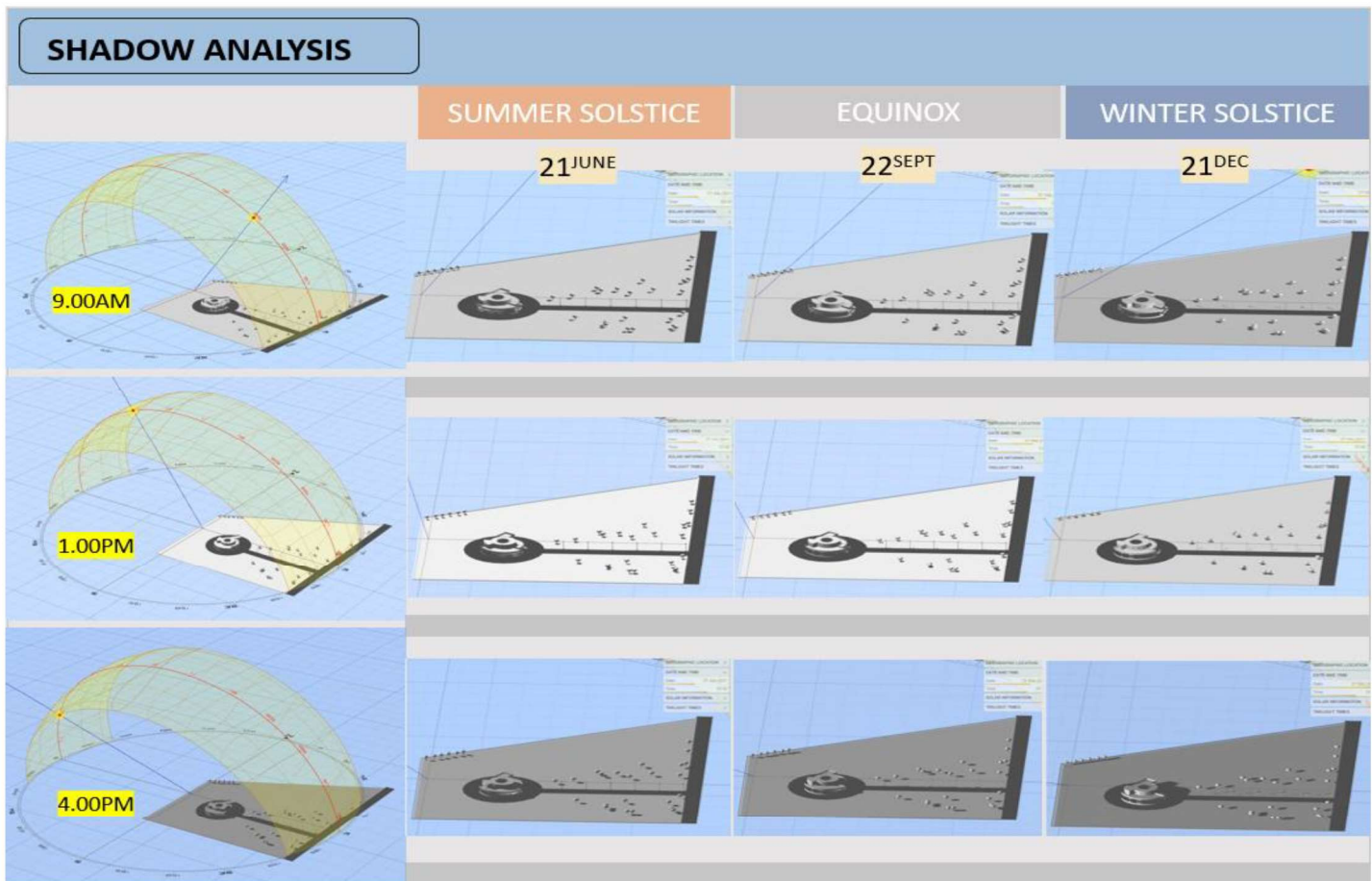


Fig.4.2.1 Shadow conditions on different period

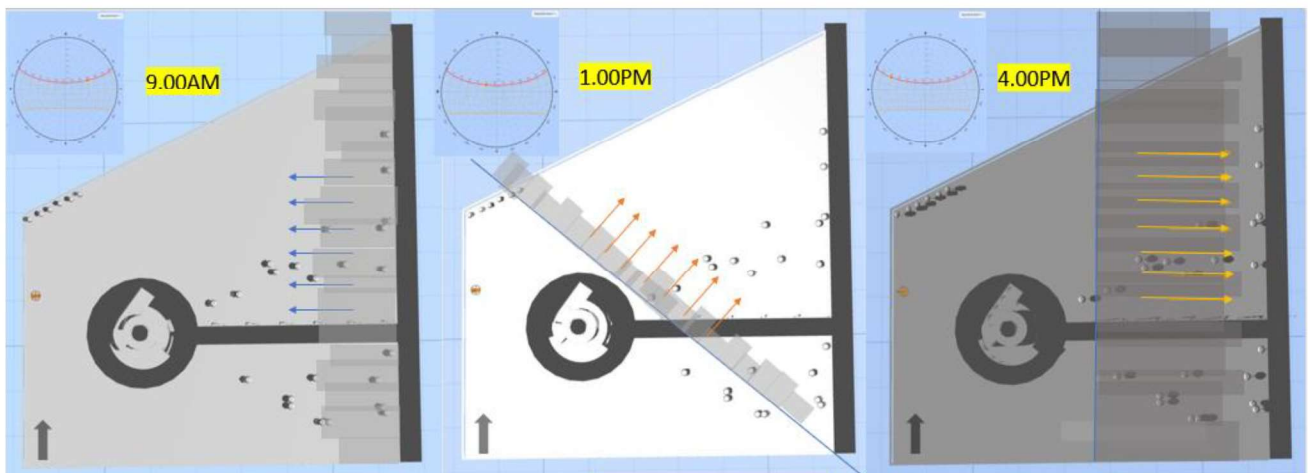


Fig.4.2.2 Shadow movement on site

4.3 OVERALL RESULT OF PASSIVE AND ACTIVE ITERATIONS

For the selected 45 degree tilted underground platform, daylight analysis has been done for different courtyard and atrium types. From the analysis, one of its best types will be chosen based on the average lux level that achieves for the spatial type. As per SP- 41 day lighting standards, lux range of about 150–200 lx is recommended for museum display areas and the spaces like library, record room and office spaces require an average of 500lx. Following such standards in order to achieve good visual comfort in underground structures, the average lux range of about 500lx is set as target in the base case. The lux range attained courtyard and atrium types will be carried out to the spatial planning of the museum underground galleries.

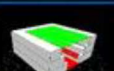
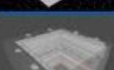
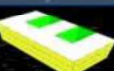
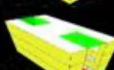
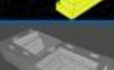
	INFERENCE							
	ITERATIONS	AREA	9.00AM LUX	1.00PM LUX	4.00PM LUX	LUX EFFICIENCY	MATERIAL	LUMINOUS EFFICACY
	COURTYARD	260 SQM	462 lx	490 lx	310 lx			
	COURTYARD WITH SKYLIGHTS G-1 LEVEL	260 SQM	525 lx	598 lx	504 lx	✓		
	COURTYARD WITH CLERESTORIES	260 SQM	505 lx	538 lx	304 lx			
	SKYLIGHT COURTYARD WITH HELIOSTAT (FOR DEEPER LEVELS) G-2 LEVEL	260 SQM	AVERAGE 539 LUX			✓	Active heliostat With fresnel lens And collimator	4496 lm SUN LUMINARES 58W light load
	ATRIUM	625 SQM	390 lx	410 lx	378 lx			
	STEPPED ATRIUM G-1 LEVEL	625 SQM	513 lx	498 lx	376 lx			
	STEPPED ATRIUM WITH SOLAR SUN COLLECTOR (FOR DEEPER LEVELS) G-2,3 LEVELS	625 SQM	AVERAGE 596 LUX				Solar sun collector, Optic fibres with sun luminaires	4308 lm sun luminares 55W connected load
	E – SHAPED ATRIUM	628 SQM	402 lx	378 lx	264 lx			
	H – SHAPED ATRIUM	628 SQM	329 lx	285 lx	224 lx			
	S - SHAPED ATRIUM	620 SQM	470 lx	492 lx	385 lx			
	S – SHAPED STEPPED ATRIUM	620 SQM	506 lx	518 lx	480 lx	✓		
	S- SHAPED STEPPED ATRIUM WITH SOLAR SUN COLLECTOR	620 SQM	AVERAGE 517 LUX			✓	Solar sun collector, Optic fibres with sun luminares	4308 lm sun luminares 55W connected load

Fig.4.3.1 Iterations of courtyard and atrium types

CHAPTER 5 FINAL PROPOSAL

5.1 RETROFIT THE EXISTING BUILDING

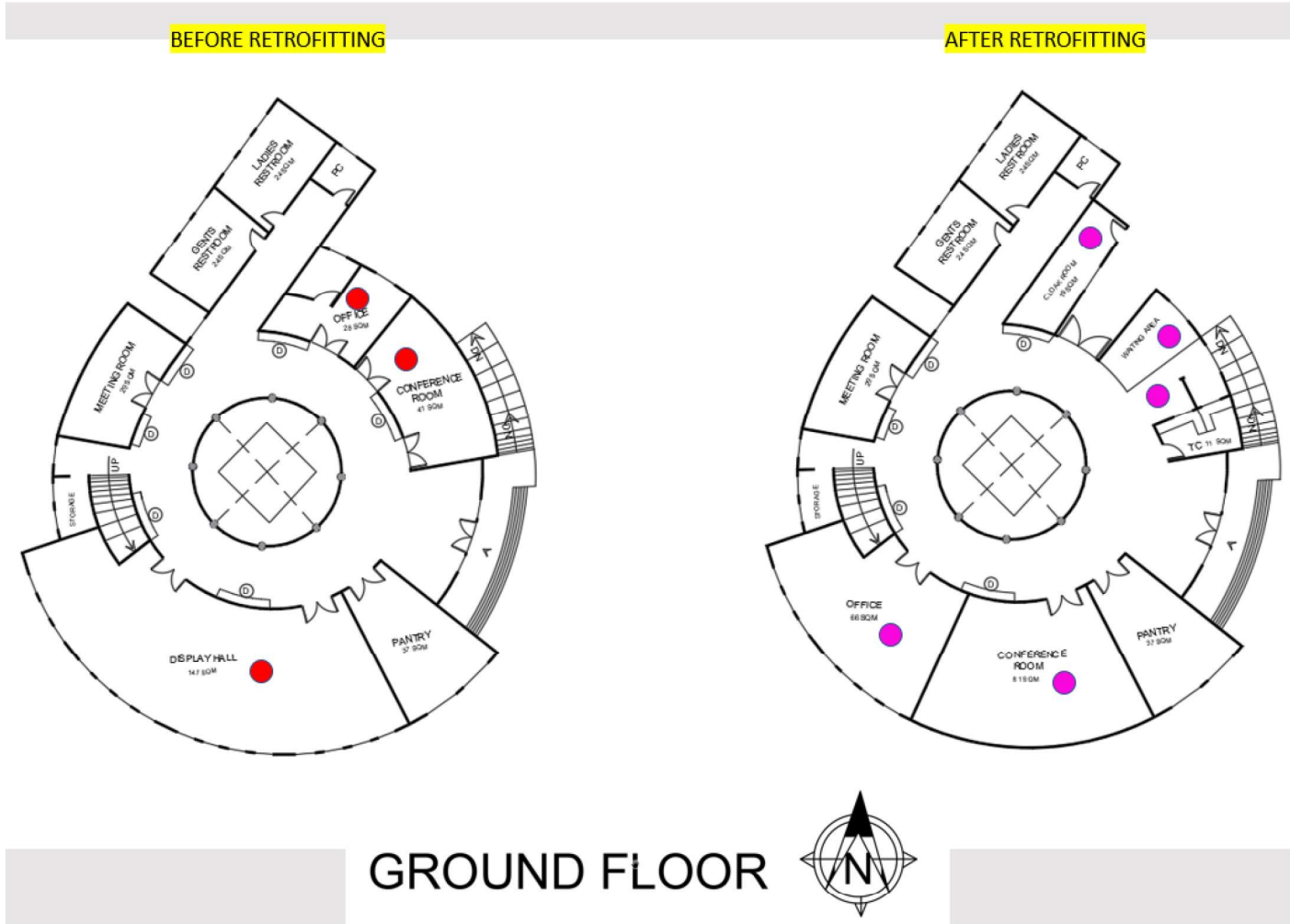


Fig.5.1.1 RETROFIT GROUND FLOOR PLAN

5.2 FINAL SITEPLAN

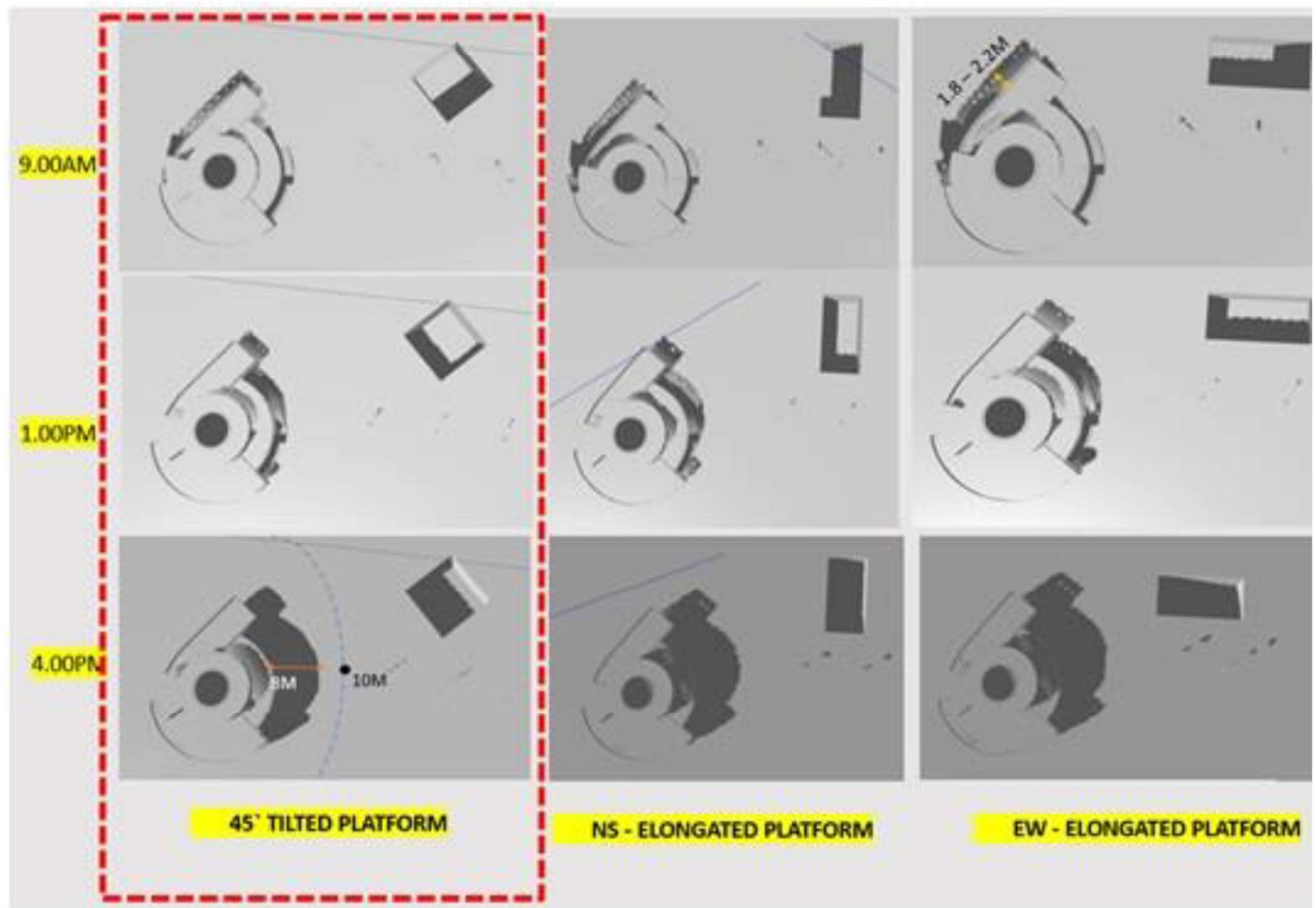


Fig.5.3.1 Iterations of different underground structures

INFERENCE OF SHADOW ANALYSIS

9.00AM: In the 45-degree tilted courtyard, about $\frac{1}{2}$ of the floor illuminates sunlight to the base floor. Whereas on the other two types (NS and EW elongated platforms) nearly $\frac{3}{4}$ of the floor is shaded.

1.00PM: Courtyard tilted on 45 degree performs much better than the other two types, nearly $\frac{3}{4}$ of the floor is illuminated than the North-South and East-West elongated platforms.

4.00PM: In other two types, almost the entire floor is in shadow but the 45-degree tilted courtyard illuminates light into the short east face in such a way the 45-degree tilted courtyard performs much better than the other two types.

5.4 COURTYARD DAYLIGHT ANALYSIS

For the proposed underground galleries with the passive method (courtyard cut outs and the dome roof shells) the G-1 level of courtyard space attains the average lux range of 500lx in daytime. But the range achieved in the G-2 level doesn't satisfy the SP-41 standard requirements. So, to improve the efficiency of lux in G-2 level, the active heliostat day lighting system is used to achieve the required lux range in space.

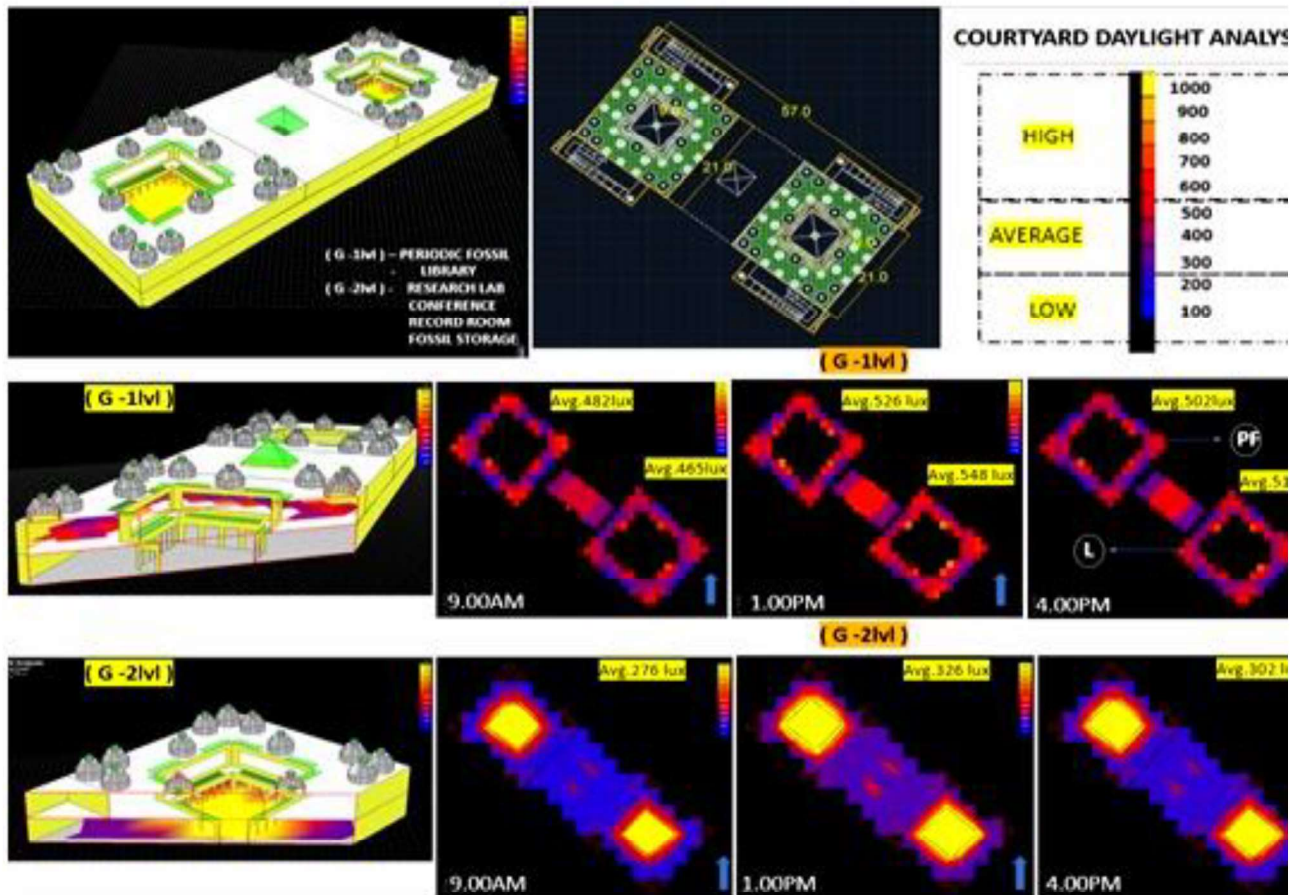


Fig 5.4.1 Iterations of different underground structures

From the active Heliostat day lighting system, with the selected sun luminaire type it illuminates daylight into the space of about 523lx range in the G-2 level and satisfies the SP- 41 lux requirement. In the wall surface, achieved lux range is between 100-300 lx from 9.00AM to 4.00PM which is more sufficient for the spatial function and for occupant's visual comfort.

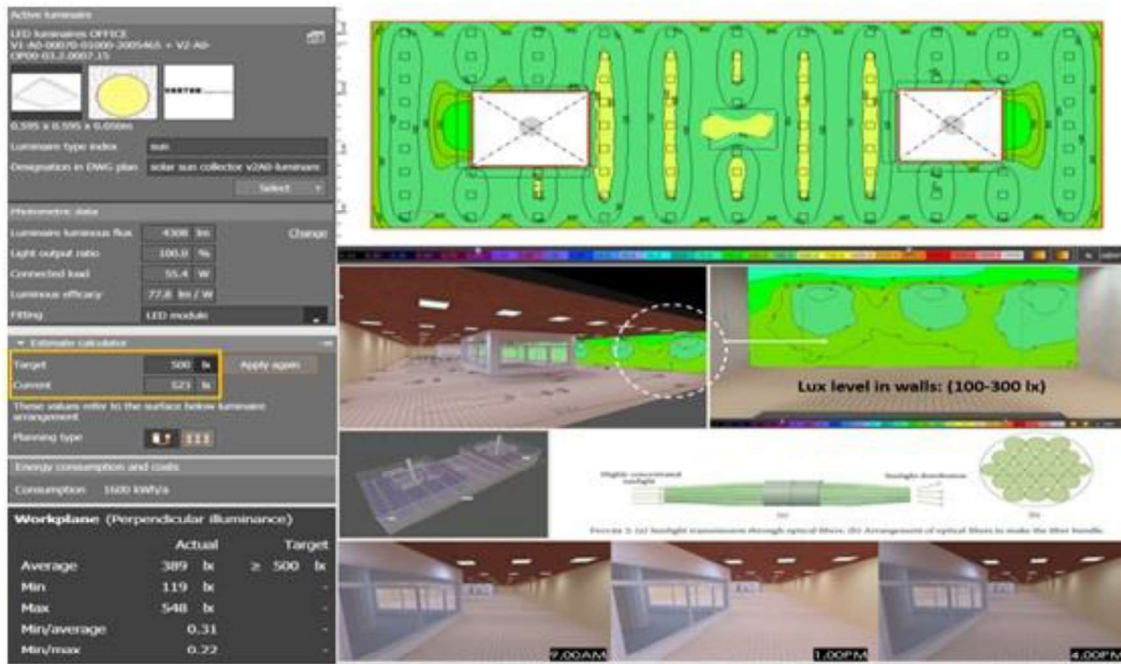


Fig 5.4.2 Daylight analysis of courtyard in Active method

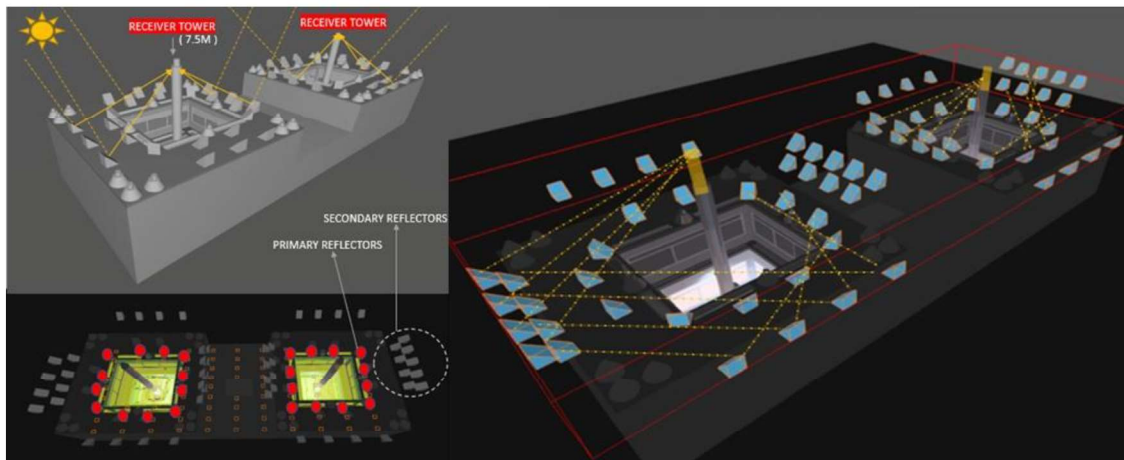


Fig 5.4.3 Active heliostat arrangement in courtyard

5.5 ATRIUM DAYLIGHT ANALYSIS

From the passive method (Stepped planning, roof dome shells and through the larger width atrium opening) the achieved lux range is about 546lx in G-1level and for the G-2 level, the achieved lux range is about 440lx, which is more than the required range of 350lx for the 3D-theatres and allied spaces. So, there is no need of using active systems in this floor. But for the G-3 level, an active system is much needed to improve indoor light efficiency. The level achieved here is only about 300lx average range, through the passive planning. Hence as per standards, the floor level for the space planetarium should have the range of about 400lx.

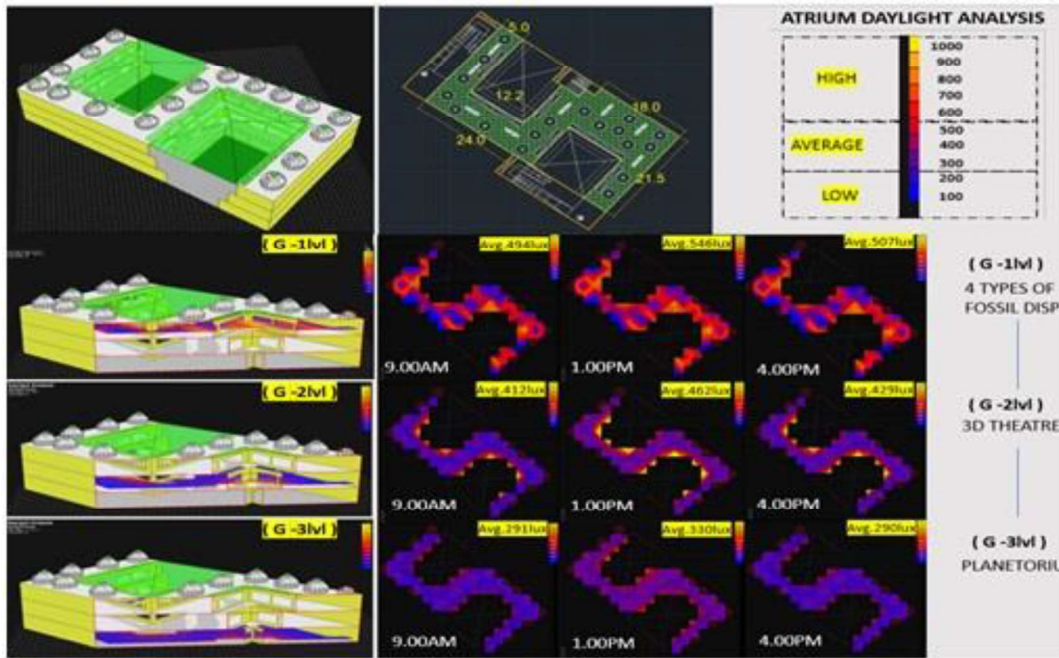


Fig 5.5.1 Daylight analysis of atrium in passive method

From the active sun collector, the lux range attained on the G-3 level is 517lx, which achieves the target range of 500lx and the spatial daylight requirements. The selected sun collector type is SP4-8.2 sun collector, with 8 light points. Each light point will give about 700-1100 lumens and the system also consists of fiber optics cable, up to a length of 100meters. It helps to distribute light to the indoors and minimize the annual energy cost.

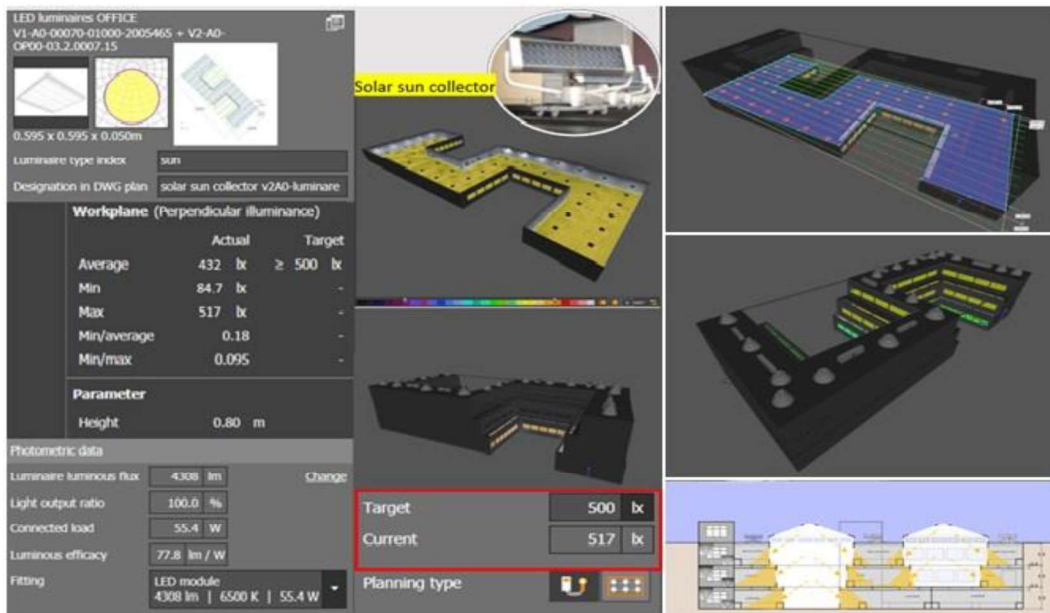


Fig 5.5.2 Daylight analysis of atrium in Active method

5.6 SIMULATION RESULTS

The result shows the attained lux level in each floor by the passive and active methods of courtyard and atrium.

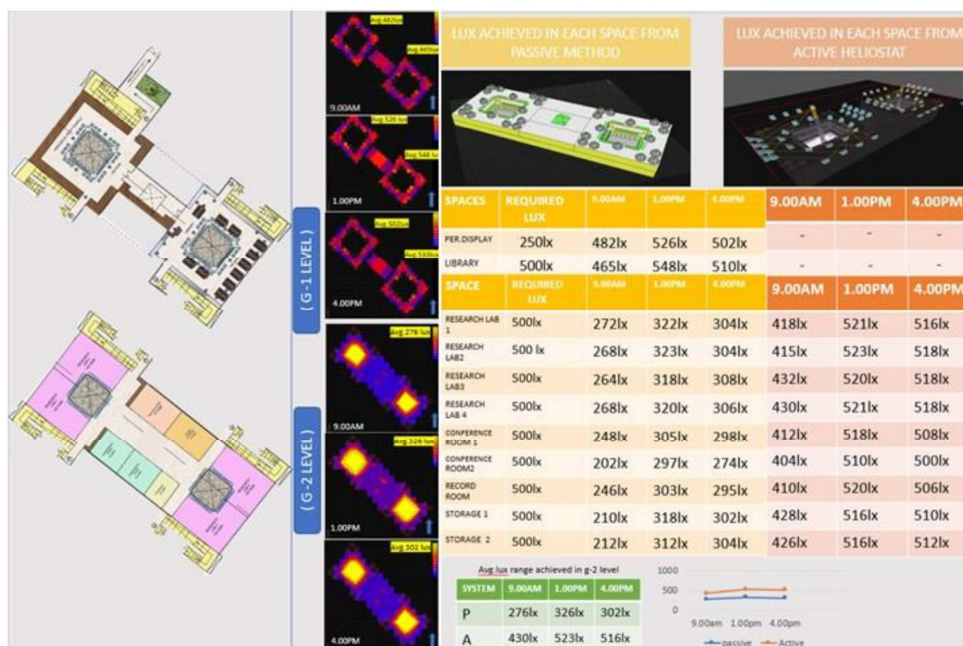


Fig 5.6.1 Floor wise Lux Range in Courtyard

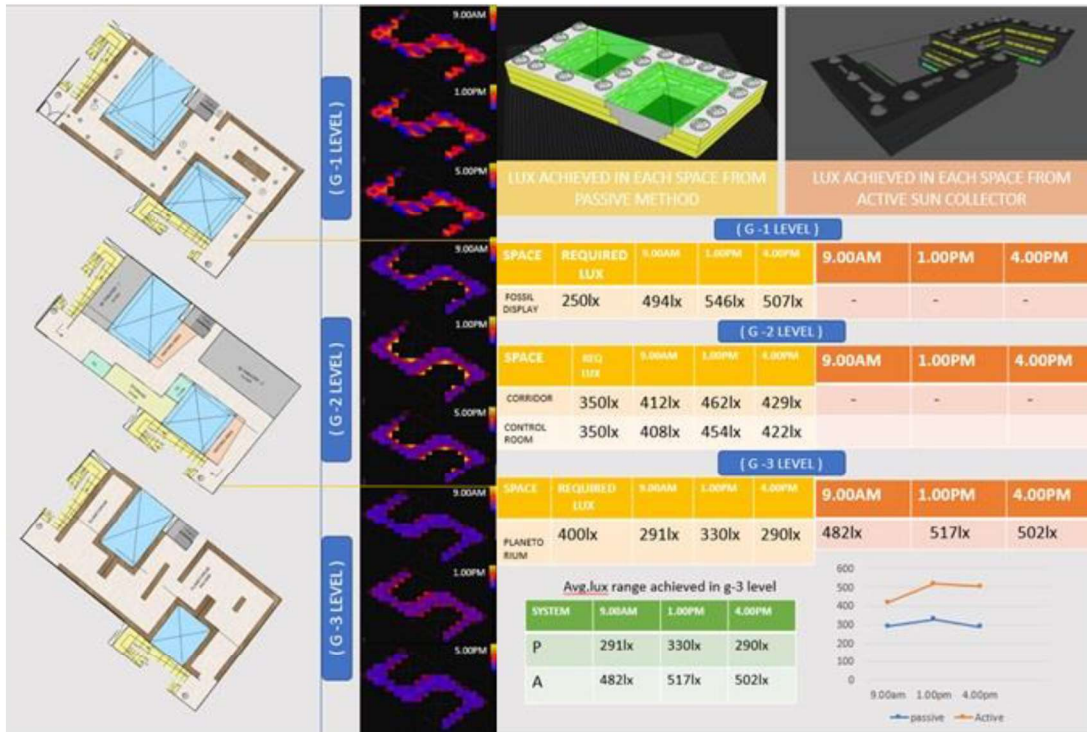


Fig 5.6.2 Floor wise Lux Range in Atrium

6. CONCLUSION

The result of this paper presents an attempt for designing underground platforms by optimizing daylight through the active and passive methods. The daylight analysis of both courtyard and atrium in underground platforms shows an efficient way of achieving lux range in each space through the selected strategies. The proposed method helps to achieve IEQ (Indoor Environmental Quality) credit of IGBC Green building rating system under daylight criteria.

In future the demand to build the underground structure may increase. This proposed designed strategy would be referred as a benchmark for such future sustainable projects. In several metropolitan cities, providing Daylight and HVAC is the major issue while designing heavy underground structures. Taking this research as a base, the day lighting issues can be resolved in urban underground projects such as Multilevel Basement Parking, Metro Stations, Office Spaces, and Hyper Markets etc. By further research, the proposed design features can be enhanced in many ways by considering the other parameters such as Indoor comfort and HVAC.

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