Future Manifestation of Lighting in Sacred Landscapes Through Analyzing the Existing Sacred Structures

E. Uma Mouthiga, R. Vignesh

***Abstract**: Lighting in sacred structures is an important part of architecture as it has physical and psychological impact on visitors and also influences how well a space is perceived. This research study intends to demonstrate that how expressions of light and daylight factor have a significant impact in the structure's design. The study utilizes a mixed method approach, with qualitative and quantitative analysis of lighting levels and visual integration of numerous sacred spaces, studied and compared through case studies. The findings aided in the development of guidelines for individual, collective and sacred lighting of landscapes in order to heighten the sense of sanctity inside the area. Since this study mainly focuses on natural illumination in the horizontal plane, more research can be conducted focused on the use of artificial lighting levels. The vertical plane, which incorporates walls and openings, can also be considered to see how it alters interior illumination.*

***Keywords**: Daylight Factor, Natural Illumination, Religious Structures, Sacred Landscape, Sacred Lighting.*

I. INTRODUCTION

The treatment of light in all scared landscapes has a common connection with all of the world's religions. Inside any sacred landscape, the worshippers' feeling of receiving has a distinct syntax. This research will uncover that common trait, and the common trait's values will be unveiled using all types of data manipulations. This research focuses on how light is used to create architectural design and how inferences can be used in modern architecture to represent spatial, aesthetic, and emotional values in modern structures.

A. Objective

To investigate the physical and psychological impacts of lighting in sacred structures on visitors, as well as how this phenomenon influences the architecture style of the structure, regardless religious differences. The demonstration of how the light component plays an important role in welcoming guests into the area and guiding them to the sacred path within the structure. This also includes how the building's elements were utilised to create the light. Regardless of religious differences, reception and the journey to a sacred or holy backdrop share a similar grammar.

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B. Scope

This research will focus on that specific common grammar, namely the entry, the path and the sanctum. This research is mostly concerned with natural illumination in the horizontal plane.

C. Methodology

Experimental studies using stimulation and a literature review of various sacred structures are carried out. The daylight factor is calculated and recorded in a variety of structures. To prove the objectives, qualitative, quantitative, and comparative analyses will be used.

II. PERCEPTIONS FROM HISTORY

A. Natural Light inside the Sacred Structures

Inside a developed environment, the importance of natural light has altered considerably, beginning with natural light as the primary source of light and steadily growing reliance on artificial light sources. With the introduction of electrical lighting and its widespread availability in the previous century, the world has changed dramatically. The usage of static artificial lighting has emphasised the growing necessity for control over illumination levels inside a place. The atmosphere and tone of a space have been affected by the motion of the sun throughout the sky as well as the seasonal changes. While this transition has increased energy reliance, it has also removed the interior from having a strong relationship with the exterior. The strong rays of the sun entering through the profound darkness of a cave are mentioned in early reports of the use of natural light. Natural light has been a primary source of illumination in various types of shelters erected by humans in the pursuit of survival and comfort throughout this time, with differing degrees of control. Light openings cut into diverse surfaces with an imaginative and artistic sense have generated an exclusive sensation of area in a range of methods. The way daylight enters a space and casts shadows on various surfaces has long been associated with profound symbolic significance.

B. Symbolism of Daylight

Sacred light is not associated with a specific deity, religion, or place of worship. The light and darkness of nature, the emergence and extinction of any form, crucifixion and rebirth are all examples of phenomena that are beyond our comprehension. The use of natural light in religious areas has long been important.

People have been orienting their new way of life on the lights of the sky since the dawn of civilization, associating them with cleanliness, purity, knowledge, and cosmic strength. The proportioning systems were used to comprehend and assign significance to the sun's and moon's rhythms and cycles. Through various lighting systems, this idea was later implemented into religious architecture. The processional route in Egyptian temples ran through a hypostyle hall that grew deeper and darker until it reached the cult pictures, which were only lighted on certain days by the rising sun, appearing brilliantly out of the darkness. In the same way, only a few small windows pierce the enormous walls of Romanesque domes, delivering rays of light through the darkness that were considered to come directly from God. The walls of Gothic churches were replaced with magnificent coloured glass windows, creating a synthesis of tangible and immaterial light. The regulation of light in churches was perfected throughout the Baroque period, reaching a pinnacle in the orchestration of light in architecture.

C. Movement Towards Light

Certain areas of the spatial envelope have a higher relative brightness, which works as focal accents. A visitor's movement in a structure is directed towards light. The greater the difference in brightness or contrast among two materials, the more action is given. Because it is difficult to combine performance specifications with the artistic play of illuminance, this becomes a significant consideration in the processes and dynamics of spaces within a building. When judging brightness of a surface, the visual impression of space relies on contextual information. The foreground and backdrop have a significant relationship that helps determine how a space is perceived in terms of existing light levels. The context may shift as you walk through a space; for example, a brilliant surface against a dark background may appear dim when viewed against a well-lit light colour material. Depending on the information provided by the two surfaces, this could shift the visual interest from the foreground to the background.

III. CASE STUDIES

A. Case 1 : Church of Holy Apostles, Thessaloniki

The chapel is positioned with its major axis eastbound, as is the case with many Christian structures, in order to acquire the first light of the day in the altar area. The axis, as per Potamianos (2000), is directed east with a little tilt to capture the morning sun on the day of the church's festival. The chapel is built in the shape of a five-domed cross in a square. The approximately square (17.6-18*19.3m) design includes the naos, an esonarthex, a triconch shrine in the east, an exonarthex in the west, lateral ambulatory wings, and terminal horizontal chapels.

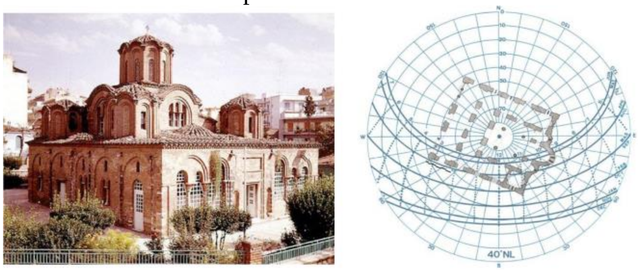

Fig.1(a)View of Church of Holy Apostles (b)Orientation of the church

1.1. Descriptive Analysis of interior lighting levels

Experimentation was conducted using the Turner's Depthmap software. Except for the altar zone around sunrise and the area around the sidewall apertures, brightness levels are low, and luminance distribution is varying. However, the lighting level of interior are dictated by the space's architecture. The architectural layout in zones corresponds to the brightness distribution, which is also divided into zones. Because the windows are on the sides, daylight levels are often low, and dome lighting is insufficient to raise the brightness levels. The church's indoor illumination, in combination with the structure's design, artwork, and decor, produces an environment suitable for orthodox rituals. In certain realms, light is revealing, yet in others, the scarcity of darkness and light create mysterious emotions and the anticipation of revelation.

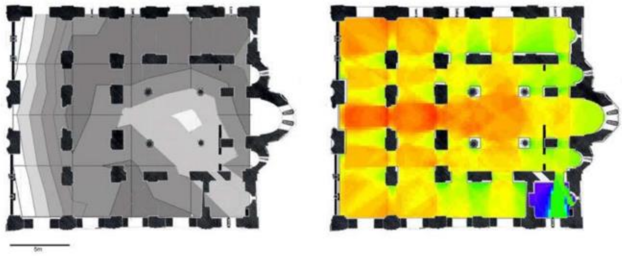

Fig.2 (a)Luminance levels of Church of Holy Apostles (b)Daylight levels of Church of Holy Apostles

B. Case 2: Alaca Imaret Mosque, Thessaloniki

With the mihrab wall pointing southeast and the main axis extending northwest to southeast from the entryway to the mihrab, the mosque faces Mecca. These two cubes make up the basic rectangle central praying space. The massive rectangular main prayer space is encircled by 11-meter-wide domes, and the mihrab is placed in the core of the south-facing wall, just across from the main entrance. Along both side of the mosque's worship space are two smaller rooms with spherical domes that are shorter and narrower than the larger ones. The separate prayer hall and undeniable square and rectangular components, on the other hand, are a long reach from Byzantine cathedral interior's merging space.

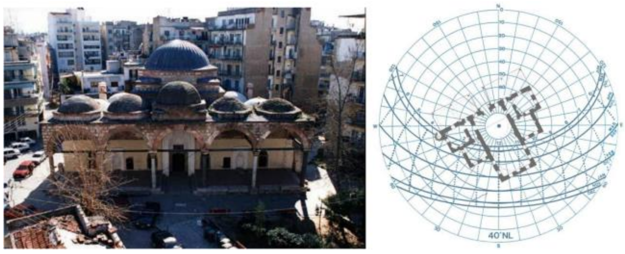

Fig.3(a)View of Alaca Imaret Mosque (b)Orientation of the mosque

2.1. Descriptive Analysis of interior lighting levels

Experimentation was conducted using the Turner's Depthmap software. During the hours when sunlight penetrates the walls, however, on the vacant walls, there is a variation of light patterns. Nonetheless, due to structural alterations, the intended illumination level in the inside would

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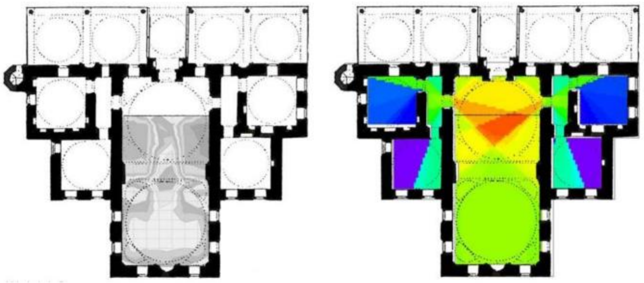

Fig.4(a) Luminance levels of Alaca Imaret Mosque (b)Daylight levels of Alaca Imaret Mosque

have been greater and the surrounding urban fabric. The two domes appear to be quite bland, while similar structures with holes appear to have a substantial variation in style. Through its diffusion in the interior, light enhances this quality. Light shafts and brilliant intervals, on the other hand, add visual interest and a sense of uplift. Visitors can then analyse the place and proceed to their intended location. When lighting conditions are compared to the mosque's spatial arrangement, the most visually integrated regions have the lowest brightness levels.

C. Case 3: Brihadheeswara temple

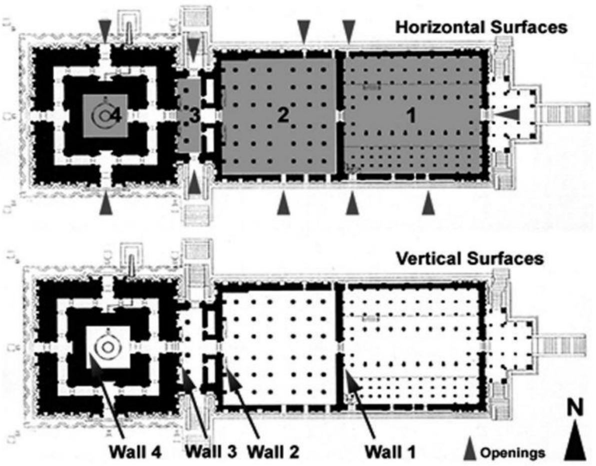

Fig.5(a)Horizontal surfaces of the Brihadheeswara temple (b) Vertical surfaces of the Brihadheeswara temple

Material (granite), texture, and physical properties were assigned to the model's surfaces and openings. Considering the geographic position, date, time, and sky conditions, the system of light (natural light) were influenced. The simulation focused on sunrise and sunset on March 21st (the equinox), which are spiritually significant in Hindu religion.

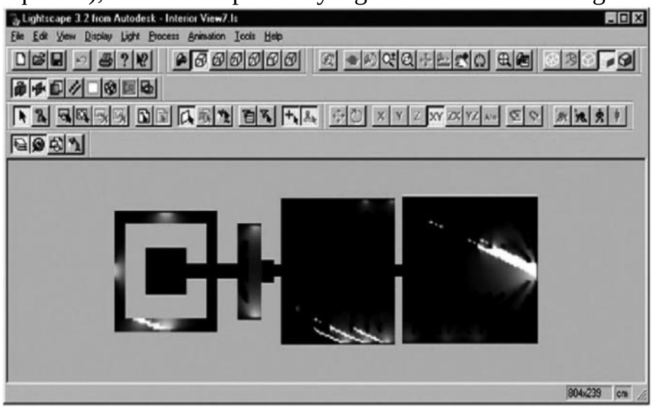

Fig.6 Lightscape's main window and a sample of the simulation's single image

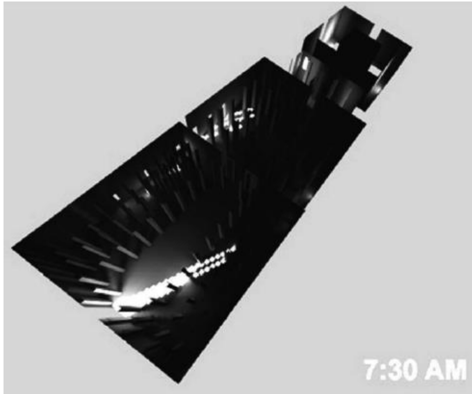

Fig.7 A captured image of the walk-through lighting animation

D. Case 4: Chennakeshava temple

Fig.8 Views and entry of Chennakeshava temple

The Hindu temple called Chennakeshava temple is in Belur, the Hassan district of Karnataka, India, that's been erected in the 12th century. In 1117 CE, King Vishnuvardhana built it on the beds of the Yagachi River in Belur, formerly known as Velapura, an ancient Hoysala Empire capital. The temple took three generations to construct and required 103 years to finish. The ekakuta vimana (mono shrine) design of the temple is 10.5 metres by 10.5 metres. Its design is a blend of Nagara style from North India and Karnataka style of south India. The sanctum is surrounded by a broad, open platform that functions as a circumambulatory route.

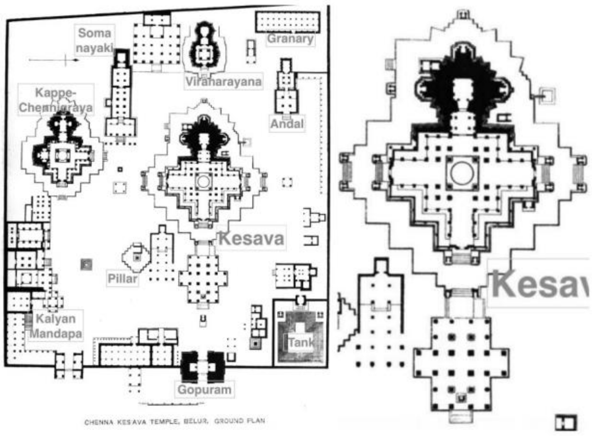

Fig.9 (a)Plan of the whole temple complex (b) Plan of the main shrine

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4.1. Descriptive Analysis of interior lighting levels

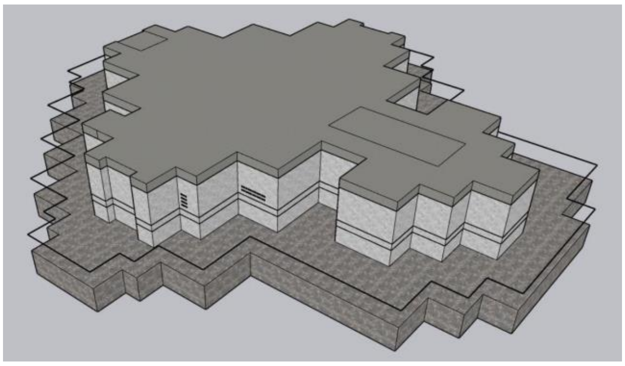

Fig.10 3d block developed for simulation

Because the temple complex is centrally placed, visitors will approach the temple directly into the hypostyle hall. The steps leading to the hypostyle hall are elevated above the raised platform, which will serve as a circulation corridor around the main shrine.

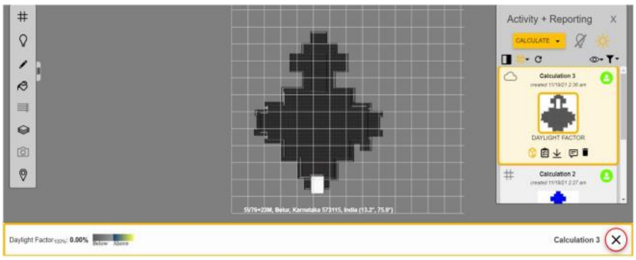

Fig.11 Graph showing daylight factor

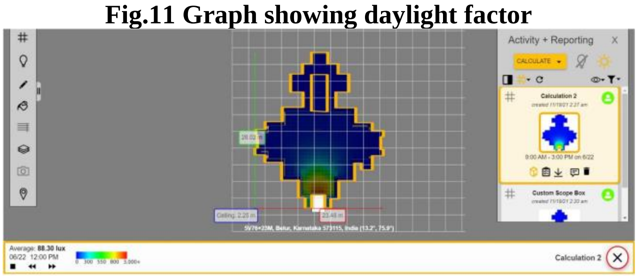

Fig.12 Graph showing average lux distribution inside the complex

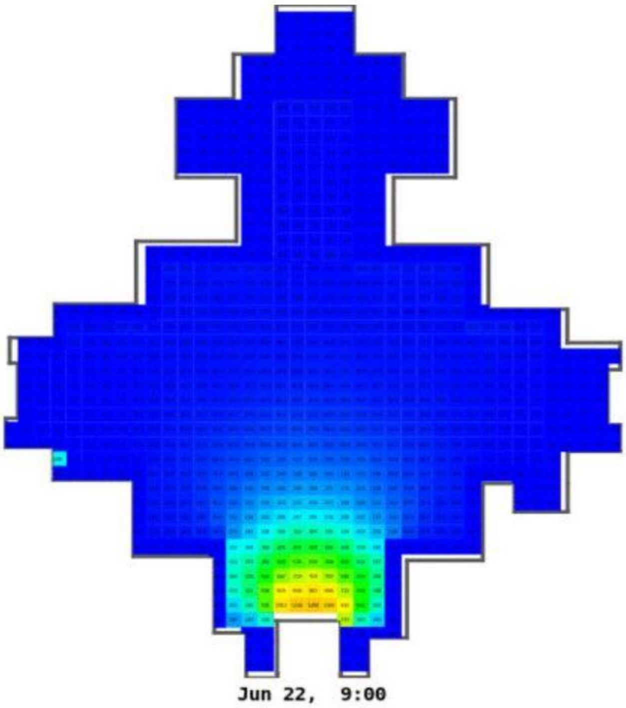

Fig.13 Illuminance grid generated

E. Case 5: Airavateshwara temple

The temple is built on a raised platform with plenty of room for walking. The interiors of the hypostyle hall will have a minimal number of openings that we can view. The colonnaded façade that ran the length of the raised platform provided light for the colonnaded hypostyle hall. The agra mandir has a 7 m (23 ft) square porch added to one side. From east to west, it has ornately carved steps. The bali-pitham is located to the east of the main podium. It's unique because it's made out of elaborately carved balustraded stairs. They create a musical note when someone walks or steps on them. As a result, they're known as the "singing steps."

Fig.13 Views of Airavateshwara temple

At Darasuram, Arulmozhi varman constructed the Airavatesvara temple complex, which includes a 24m vimana and a stone image of Shiva. The Cholas' extraordinary accomplishments in architecture, sculpting, paintings, and bronze cast may be seen in the temples. The visitors' axis will initially be orientated towards the mandapa or hypostyle hall through the steps that run around the circum entablature. The path will then lead to the garden and the surrounding colonnaded mandaps, eventually leading to the garden space.

5.1. Descriptive Analysis of interior lighting levels

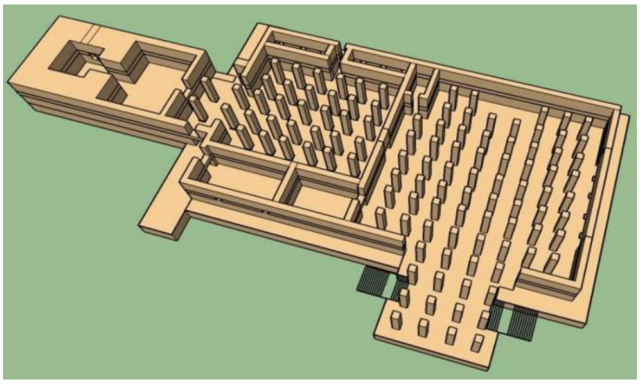

Fig.14 3d block developed for simulation

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People will enter through the steps on the left side of the entablature, which lead directly to the little shrine. Along the entrance to the centre vestibule, the pathway has a low light level. The colonnades block light from both sides of the entablature, resulting in this effect.

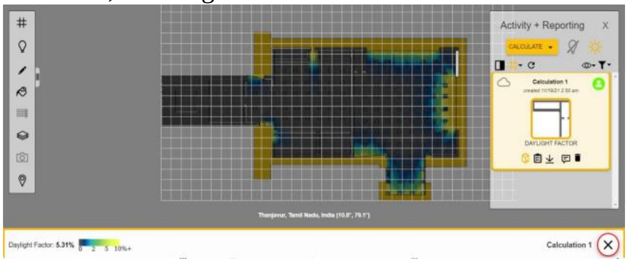

Fig.15 Graph showing daylight factor

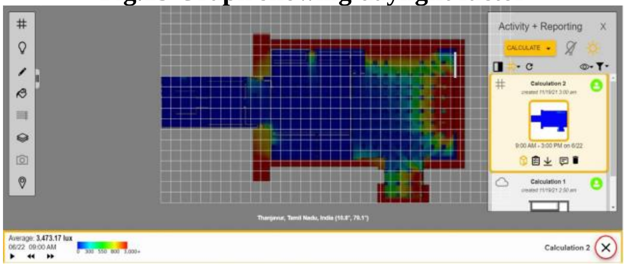

Fig.16 Graph showing average lux distribution at 9 am

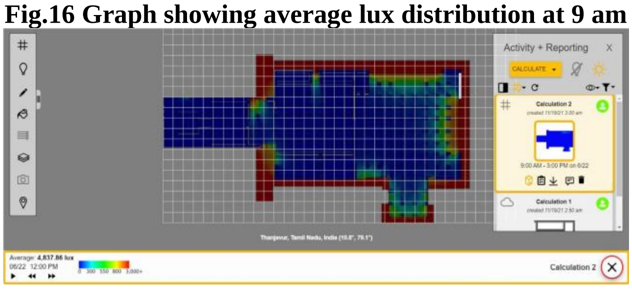

Fig.17 Graph showing average lux distribution at 12 pm

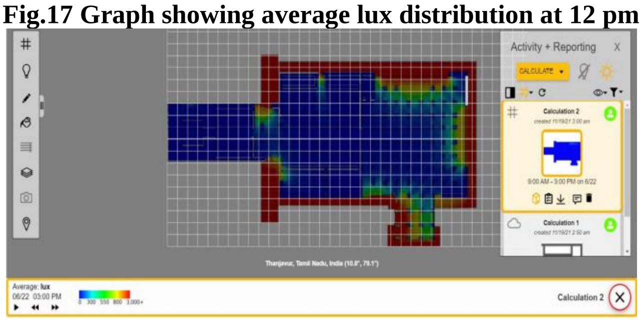

Fig.18 Graph showing average lux distribution at 3 pm

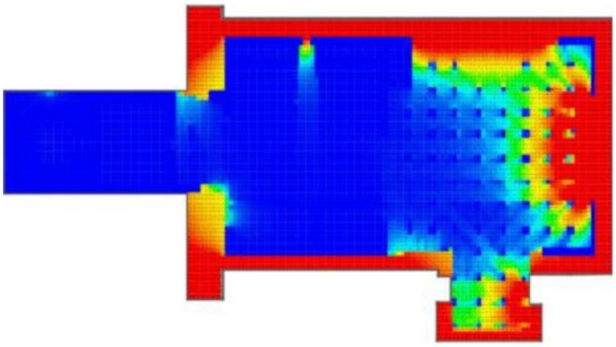

Fig.16 Illuminance grid generated

IV. ANALYSIS

A. Case 1: Church of Holy Apostles, Thessaloniki

When lighting levels are compared to spatial metrics, the esonarthex's central section is one of the least well illuminated areas of the structure, while the place under the dome is one of the best illuminated.

As a result, visitors situated in the most optically advantageous place gain a clear sight of the high-illumination area beneath the main dome, which supports the ritual journey from the exterior to the inside of the church. As you get further along the major axis of the cathedral, the primary transition from the external to the exonarthex comes with a decrease in levels of light, producing a smooth shift from the exterior to the interior of the chapel. As you come closer to the middle dome, in which the illumination level are at their highest, there is another drop followed by a fast surge. It's possible that the individual adapts to the poorly lit interior after approaching the church and going in through the enclosed passage (narthex), i.e, the transition region, and afterwards searches out illumination as a directing factor. The lighting pattern will be influenced by the movement of the people. People will make their way from the narthex to the centre of the dome, where the lighting is brightest.

B. Case 2 : Alaca Imaret Mosque, Thessaloniki

The first section is the area immediately adjacent to the door, which also serves as the entrance to the adjacent chambers connected to the main prayer hall. The light level has dropped close to the entrance and raises as one moves through the prayer hall to the mihrab area, emphasizing the layout. The process of passing through areas of changing light levels creates a comfortable transition from the magnificent facade to the mosque's interiors, despite the fact that the mosque's decor is not gloomy enough to be undesirable while entering. Due to its flexible plan architecture, the masjid is an omnidirectional space. The non-directional confinement of the interior region by enclosure, instead of the following attributes as in a church, is the defining feature. Even yet, the visual integration core is dimly lit and situated on the periphery of the main center area, whether in a chapel, where the esonarthex is the most optically connected position. The fundamental rites are related with the highest illuminance areas on both buildings, as light moves from the outside to the darkness and returning to the brilliant at the minaret or the major naos.

C. Comparative analysis of case 1 and case 2

Table- I: Lighting Details for Church

Action-Place	Quantity		Quality		
	Illuminance lm/m^2	Position	Illuminance Distribution	Colour of Light	Direction, Shadows
Desk	100-200	Horizontal	General	Warm-white	Diffuse, Shadowless
Altar	300	Vertical/Horizontal	Local	Warm-white	Diffuse, Shadowless
Pulpit	300	Vertical/Horizontal	Local	Warm-white	Diffuse, Shadowless

Table- II: Lighting Details for Mosque

Action-Place	Quantity		Quality		
	Illuminance lm/m^2	Position	Illuminance Distribution	Colour of Light	Direction, Shadows
Reading-Rahle	300	Horizontal	Local-General	Warm-white	Diffuse, Shadowless
Namaz-Mihrab [vi]	300	Vertical	Local-General	Warm-white	Diffuse, Shadowless
Namaz-Prying	100	Horizontal	General	Warm-white	Diffuse, Shadowless

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D. Case 3: Simulation results in comparison with IES standards

Table- III: Comparison of IES criteria for 'public locations in darkened environments' with the simulated mean levels of illumination of horizontal surfaces

	Floor I (lux)	Floor 2 (lux)	Floor 3 (lux)	Floor 4 (lux)
Average (horizontal surfaces)	118.67	75.65	313.03	0.40
Public space with dark surroundings	30	30	30	30
Short temporary visits	75	75	75	75

Table- IV: Comparison of IES criteria for 'public locations in darkened environments' with the simulated mean levels of illumination of vertical surfaces

	Wall I (lux)	Wall 2 (lux)	Wall 3 (lux)	Wall 4 (lux)
Average (vertical surfaces)	38.33	3.27	168.64	0.43
Public space with dark surroundings	30	30	30	30
Short temporary visits	75	75	75	75

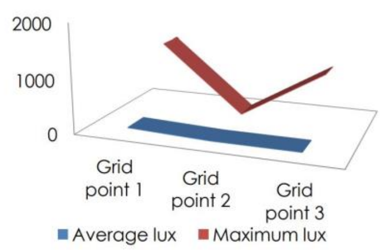
E. Case 4 : Chennakeshava temple

Table- V: Daylight analysis report and findings

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Name	Number	Date	Area (sq n	Height (m	Grid Point	Avg (lux)	Max (lux)	Min (lux)	Avg/Min	Min/Avg	Max/Avg	Max/Min
2	Carrera_Marble		2021-06-2	315.03	0.76	816	64.39	1287.52	0	Infinity	0	20	Infinity
3	Carrera_Marble		2021-06-2	19.09	0.76	55	7.11	15.65	4.02	1.77	0.56	2.2	3.9
4	Carrera_Marble		2021-06-2	113.53	0.76	268	1.12	296.08	0	Infinity	0	264.38	Infinity
5	Carrera_Marble		2021-06-2	315.03	0.76	816	93.94	1889.83	0	Infinity	0	20.12	Infinity
6	Carrera_Marble		2021-06-2	19.09	0.76	55	9.15	15.46	5.13	1.78	0.56	1.69	3.01
7	Carrera_Marble		2021-06-2	113.53	0.76	268	2.69	701.37	0	Infinity	0	260.95	Infinity
8	Carrera_Marble		2021-06-2	315.03	0.76	816	65.81	1282.05	0	Infinity	0	19.48	Infinity
9	Carrera_Marble		2021-06-2	19.09	0.76	55	6.3	12.74	3.11	2.02	0.49	2.02	4.1
10	Carrera_Marble		2021-06-2	113.53	0.76	268	3.54	944.71	0	Infinity	0	266.5	Infinity

Table- VI: Average and Maximum lux obtained

DATE AND TIME	GRID POINT	AVERAGE lux	MAXIMUM lux
June 22, 9.00 AM	816	65.81	1282.05
June 22, 12.00 PM	55	6.3	12.74
June 22, 03.00 PM	268	3.54	944.71



F. Case 5 : Airavateshwara temple

Table- VII: Daylight analysis report and findings

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Name	Number	Date	Area (sq n	Height (m	Grid Point	Avg (lux)	Max (lux)	Min (lux)	Avg/Min	Min/Avg	Max/Avg	Max/Min
2	material		2030-06-2	44.26	0.76	98	0	0	0	NaN	NaN	NaN	NaN
3	material		2030-06-2	12.15	0.76	21	0	0	0	NaN	NaN	NaN	NaN
4	material		2030-06-2	202.31	0.76	471	2.24	97.36	0	Infinity	0	43.4	Infinity
5	material		2030-06-2	13.66	0.76	25	0	0	0	NaN	NaN	NaN	NaN
6	material		2030-06-2	33.57	0.76	64	107.51	720.86	0.03	4123.56	0	6.71	27648.78
7	material		2030-06-2	13.66	0.76	25	0	0	0	NaN	NaN	NaN	NaN
8	material		2030-06-2	2897.13	0.76	7705	3.27	335.96	0	Infinity	0	102.6	Infinity
9	material		2030-06-2	2897.13	0.76	7705	7457.11	67968.38	0	Infinity	0	9.11	Infinity
10	material		2030-06-2	34.75	0.76	64	0.03	0.29	0	Infinity	0	10.2	Infinity
11	material		2030-06-2	34.75	0.76	64	0.33	2.29	0	1512.65	0	6.99	10573.15
12	material		2030-06-2	13.66	0.76	25	0.65	2.91	0.19	3.48	0.29	4.46	15.53
13	material		2030-06-2	27.19	0.76	51	0.27	1.57	0	1065.23	0	5.84	6224.74
14	material		2030-06-2	44.26	0.76	98	0	0	0	NaN	NaN	NaN	NaN
15	material		2030-06-2	12.15	0.76	21	0	0.04	0	Infinity	0	8.43	Infinity
16	material		2030-06-2	202.31	0.76	471	2	99.01	0	Infinity	0	49.46	Infinity
17	material		2030-06-2	13.66	0.76	25	0	0	0	NaN	NaN	NaN	NaN
18	material		2030-06-2	33.57	0.76	64	143.47	975.81	0	56527.73	0	6.8	384483.1
19	material		2030-06-2	13.66	0.76	25	0	0	0	NaN	NaN	NaN	NaN
20	material		2030-06-2	2897.13	0.76	7705	2.51	181.08	0	Infinity	0	72.25	Infinity
21	material		2030-06-2	2897.13	0.76	7705	10389.4	86039.58	0	Infinity	0	8.28	Infinity
22	material		2030-06-2	34.75	0.76	64	0.04	0.48	0	614812.6	0	12.99	7988489

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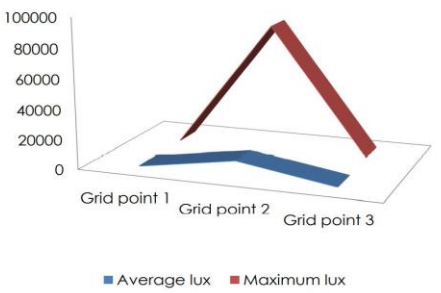
Table- VIII: Average and Maximum lux obtained

DATE AND TIME	GRID POINT	AVERAGE lux	MAXIMUM lux
June 22, 9.00 AM	7705	2.51	181.08
June 22, 12.00 PM	7705	10389.40	86039.58
June 22, 03.00 PM	64	0.04	0.48



G. Comparative Analysis Of Daylight Factor With Le Corbusier's Ronchamp Chapel

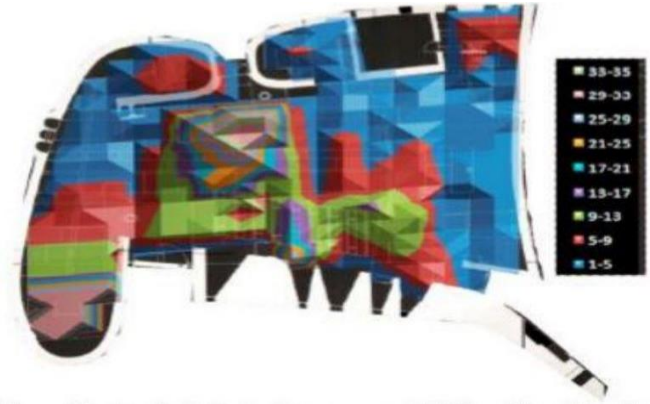


Fig.17 Daylight factor in open door environment:0.6%, 0.23% ratio of uniformity (on site measurements)

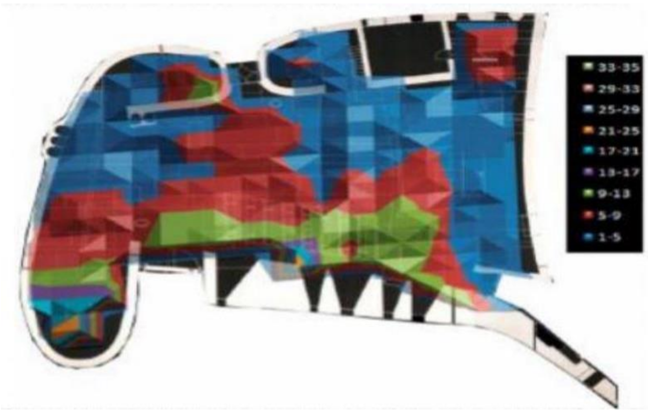


Fig.18 Daylight factor in closed north door environment, 0.3% ratio of uniformity (artificial sky)

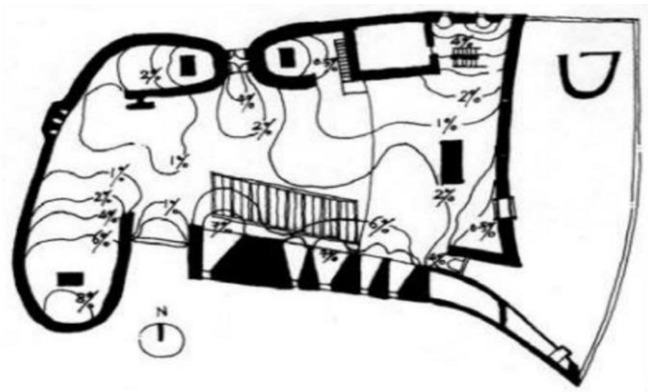


Fig.19 Contour map of daylight factor in Ronchamp chapel from Lau 2000

Stimulations of daylight is being received by the structure and how the spread of light is evenly dispersed to the desired spaces and surfaces throughout the chapel has been demonstrated, with respect to the site and context of the region. The achievement of diffused light and the controlling of daylight factor is analyzed. The treatment of light in horizontal and vertical surfaces were well demonstrated.

V. RESULT AND DISCUSSION

From the above Comparative analysis and inferences taken from the studies, the daylight factor for the Sacred structures can be framed from a value between 0.3 to 21. The lighting for the sacred structure can further be divided into three categories respectively.

1. Individual Lighting - Entry to the Structure
2. Collective Lighting – Path to the Sanctum
3. Sacred Lighting – Sanctum or towards the Focus

Guidelines framed for sacred landscapes to elevate the feel of divinity\holiness inside the structure:

1) Individual lighting is nothing but the lighting provided at the entry for the visitors inside the sacred landscape. Here, the amounts of light will me maximum. The minimum Daylight factor to be given at this level should be 21. The minimum illuminance level to be given at this level can be infinite.
2) Collective lighting is nothing but the lighting provided at the path of procession from the entry towards the sanctum or the screen where the focal point of the visitors are approaching towards the end. Here, the amount of light will be lesser than the entry and here, the minimum daylight factor to be given at this level should be 5. The minimum illuminance level to be given at this level should be 50 to 120 lm/sq.m.
3) Sacred lighting is a kind of lighting were the focal point of the visitors or worshippers reaching the surface or volume inside the sacred landscape. Here, the lowest possible amount of daylight factor should be given, to luminate the lowest possible lighting inside that particular space. The minimum daylight factor to be provided here is <1. The minimum luminance level to be provided here is 0.5 to 10 lm/sq.m.

VI. CONCLUSION

This Research concludes on guideline for sacred landscapes to elevate the feel of divinity and holiness inside any structure.

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As this Study focuses primarily on natural lighting in the horizontal plane, further study about use of artificial illumination conditions can be undertaken. The vertical plane can also be taken into account to evaluate how it affects interior lighting which includes walls and openings.

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