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The Sacred Light of Bagan: An Investigation of Natural Light at Two Ancient Temples

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Abstract

This study discusses the dynamic effect of daylight in the sacred atmosphere of famous temples in Bagan, Myanmar. Over 10 centuries, these remaining UNESCO monuments have stood still after surviving natural catastrophes and man-made disasters. A good preservation is needed to maintain these buildings. This topic arose from observations of the sacred areas lacking awareness of the value of daylight and ineffective artificial lighting. The research will investigate the daylight performance to restore the value of Bagan temples. This research will include case studies, comparative studies, and daylight simulation. In the past, monuments were taken as poor conservation work without understanding the value of Bagan. Existing artificial lighting is insufficient to cover the techniques from the past, resulting in decreased spatial quality of sacred spaces.

An investigation of the role of light and daylighting performance at sacred places has been performed by researchers to provide readers with a better understanding of the quality of light and spiritual experience at Bagan temples. This research indicates that religion impacts lighting treatments to create spiritual quality and increase devotee faith in sacred places. This research study aims to achieve three goals. First, to understand the critical role of religion in the lighting at a holy monument, and next, to examine the daylight performance of the main shrine and corridor of two Buddhist temples in Myanmar. Lastly, this research knowledge will be added as an essential reference to further studies for maintaining a spiritual quality at the place of worship when artificial lighting is developed. The research explores the daylighting technique in the two Buddhist temples built in the Bagan region of Myanmar. The temples are Ananda (Early 11th century AD) and That-Byin-Nyu (12th century AD), from two different periods of the Bagan Dynasty and comparable in size and popularity. The great Kings of the Bagan empire built these two monuments. The philosophy and religious perceptions of Kings themselves are reflected on these monuments.

Keywords

Bagan Temple; Religion; Light; Shadow; Light Quality; Architecture; Spirituality; Preservation

1. Introduction

Finding out how the spiritual quality of light and shadow was initially designed by religious and cultural principles in sacred architecture will be covered in this thesis. Moreover, how the evolution in the development of architectural technology supported the use of light in these sacred atmospheres to achieve an inspiring sanctuary. To answer this question, the study of light and shadow in two Buddhist Bagan Temples from the 11th to 12th century AD in Bagan,

Myanmar, will undergo. The periods in the Bagan Empire can be classified into three, which are (1) the proto-historic and foundation period: the early part of the 1st millennium, (2) the period of unification process and growth: 10th century to the end of the 11th century, and (3) period of peace and prosperity: end of 11th century to the end of 13th century. (Dr. Kyaw Lat, 2010) Architecture and building technology developed considerably during these centuries due to the empire's prosperity. Religion played a central role in the beliefs of Bagan society. Through religion and monuments originating from India, architecture and lighting techniques were adapted to regional conditions and cultural backgrounds during the last two periods of the empire. Natural light was one of the essential tools in these sacred spaces to offer the devotees a solid belief in religion.

1.1. Statement of Problem

Over a thousand years, these remaining ancient UNESCO monuments have stood still after surviving world wars, earthquakes, geographic changes, lack of proper maintenance, etc. In the past, monuments were taken as poor conservation work without understanding the value of Bagan. Examples include the original brick structure covered by cement mortals, painting quicklime on the wall, demolishing murals, and so on. The neglect of proper preservative knowledge by local people still leads to the threat to these ancient monuments. Likewise, most artificial lighting conditions are not adequately treated. The ancient lighting technique of the temple was designed to create light and shadow in specific function areas and enhance the spiritual experience to achieve religious goals. The existing artificial lighting is not enough to perform these techniques from the past, degrading the spatial quality of sacred spaces. Thus, these ancient temples need to receive a preservative lighting quality that does not reduce the monuments' spiritual quality or experience.

1.2. Purpose of Study

This research has three main objectives. They are as follows:

- To understand the critical role of religion in the lighting treatment of a sacred monument.
- To examine the daylight performance of the main shrines and corridors of two Buddhist temples in Bagan, Myanmar.
- To add this research knowledge as an essential reference to further studies for maintaining a spiritual quality at the place of worship when artificial lighting is developed.

There is still not much research concerning the light quality in Bagan's studies. Still, this study may offer a reference for the readers to understand the importance of light in Bagan ancient temples. The previous studies have not focused on the user's spiritual experience within the Buddhist temple in Bagan, such as dynamic light, shadow, or other aspects of lighting. Moreover, this research can benefit the readers by helping them understand the ancient daylighting technique that achieved devotion to religion at the temple. The different approaches to achieving the desired light quality can benefit contemporary design. Importantly, it can highlight the role of daylighting that impacts the spiritual quality of devotees so that the conservations of these ancient temples can improve in artificial lighting. This study may be a basic reference to further studies for maintaining a spiritual quality at worship when artificial lighting is developed. This study can contribute to maintaining an original spiritual quality of space.

2. Literature Review: Light and Shadow in Sacred Spaces

In space, light is an intangible form of element needed to define the physical border and boundary of forms by the human eye. It allows a sense of sight, spatial vision, and world perception. Though light and shadow have opposite natures, the contrast effects of these two can enhance the visual sight and dramatic moods. The usage of holy light and holy darkness was significant in many religions throughout the globe. In ancient times, sanctuary places were believed to connect human beings with their immortal superiors. Rather than other dwellings and functional buildings, light and shadow played an essential role in sacred monuments, either to enhance the belief of devotees or to optimize religious goals. Mann's (1993) discussion on the concept of light also highlights the cosmological and astronomical linkages between religious monuments and celestial bodies. He discussed that light is a vital element in the design intention, and the interplay of light and shadow creates a mystery and sacred atmosphere to connect the physical

world with the divine in a spiritual way. As the size/shape of the aperture is not just one factor for the amount of light entering the temples, the orientation of these apertures played a central role in the quantity and quality of light inside inner spaces. (Williamson, 1993)

2.1. A Role of Light in Ancient Bagan Architecture

Numerous votive tablets, paintings, and sculptures found in Bagan showed that there were Theravada Buddhism, Mahayana Buddhism, and Hindu faith, three faiths coexisting parallel during the Bagan period. There was a freedom of worship in Bagan society. (Dr. Kyaw Lat 2010) Back in the time, people had extraordinary faith in Dhamma and were zealous for their faith. The fundamental belief among society is firmly believing in good deeds. That being said, various types of religious monuments, such as stupas, temples, monasteries, libraries, museums, Dhamma schools, and so on, were numerously built for their intention of making merits. The religious monuments were constructed by the upper class of Bagan society, which included royalty, nobility, and the rich. The inscriptions mention that whenever royalty or the rich built the temple, they would donate some lands and enslaved people, known as religious slaves. The intention was to ensure that income and people maintained and looked after the monuments.

Natural light was an essential part of Bagan architecture. Daylight is a primary light source used to perform tasks inside the temple and to enhance the devotee's belief. There were several techniques to perceive daylight, an external factor, in interior spaces. They are light well, clerestory opening, peripheral opening or double-layered window, perforated window, and lateral porches. The Ananda temple, which was built in 1091 AD, had a ceiling light-well system to bring natural light to interior space and cast over the Buddha image. It is reasonable to assume that temples like Ananda, and the first with these fundamental qualities, were built during the end of the 10th century or the beginning of the 11th century AD. (Dr. Kyaw Lat, 2009) Moreover, during the period between the 11th and the 13th century AD, when Bagan architecture, decorative scrolls, and relief works flourished to their maximum extent, the appearance of Myanmar scripts and the construction of high and massive temples which get much light and temples in Myanmar style are the works created in Myanmar traditional style and manner. (Linn Sanda, 2017)

2.2. Daylighting Principle

Daylight is a pioneer light source in human life. It allows us to have a vision to perform daily tasks. Later, artificial lights such as bamboo pipes, oil lanterns, and candles were invented in the early days (500 BC). The world changed rapidly after the invention of electric light bulbs in the 18th century. Since then, it has been inevitable between modern human life and controllable electric lighting. Daylight can enter the interior space through direct and indirect sunlight through clear sky, clouds, and reflections from the ground or nearby buildings. A daylighting design that works under both clear and overcast sky conditions will also work under most other sky conditions. (Lechner 1991, 2000) Understanding natural light's direction, color, intensity, and variation can enhance light quality in an environment based on a human's physiological and psychological adaptation and predisposition to natural light. (Innes M., 2012) Lechner provided studies on daylighting design and its guidelines with suggestions focused on light, shadow, light quality, etc. These guidelines will be used in the qualitative research method in this study. They are light and shadow distribution, direct and indirect light, quality of light, light intensity, visual hierarchy, and psychological effects of light.

3. Methodology

The research examines the daylight performance and technique in two Bagan temples, which were selected from two different periods and are comparable in size and popularity. In the Bagan region, the temples are Ananda (1086 AD, Early 11th century AD) and That-Byin-Nyu (1144 AD, 12th century AD). The study will analyze topography, orientation, climate, and sky conditions. Great kings of the Bagan empire built these two buildings, and there were also philosophical and religious perceptions of the kings themselves. These two temples are chosen for their distinct representation of the last two periods in the Bagan Dynasty. Because the temples are so close together, the sky, climate, and geography are all very similar.

The full-length methodology includes a literature review, comparative analysis, and quantitative and qualitative studies, as shown in Figure 1. The literature review shows prominent connections between faith, religion, and light

in different cultures. It is to question whether religion and the intention behind the lighting quality of these Bagan ancient temples were. The author will analyze a qualitative comparative study regarding daylighting in the buildings according to design principles stated in 2.2. The criteria for evaluating lighting performance in this study follow the approach outlined in Mukherji's summary of morphological analysis (Mukherji, 2001). This method assesses lighting design based on guidelines and specific criteria proposed by Lechner (1991, 2000). A quantitative analysis is based on 3d modeling and daylight stimulation with DIALux Evo software. Due to unforeseen circumstances at the time of research, although a site observation by the researcher could not take place, the site images and HDR images were taken with the assistance of a local photographer. These images in different exposures generate an HDR in various formats, such as false color and analytics.

Since the summer solstice on June 21 and the winter solstice on December 21 are two significant critical points in Earth's yearly cycle that result in the longest day in the summer and the shortest day in the winter, which affects the amount of light received, the author chose these two dates to research the daylighting simulation. Around the time of the Thingyan Festival, on April 10, HDR photos were taken. In terms of both religion and culture, this is the most widely celebrated event in the nation. At the moment, temples are open from 8 am to 5 pm. For the study, three different times of day—9 am, 12 pm, and 4 pm—were selected to conduct daylight simulation and HDR photography.

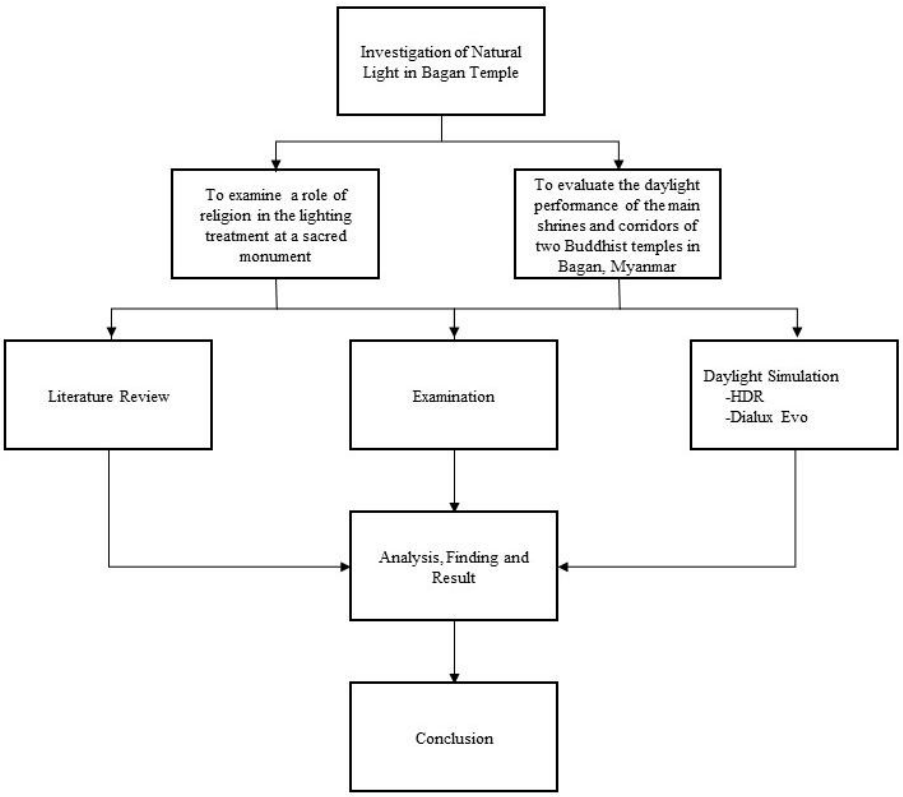


Figure 1: Method of Research Chart (made by the author)

3.1. Daylight Simulation Method

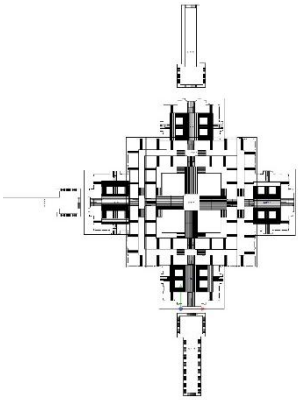
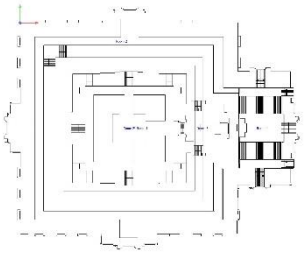
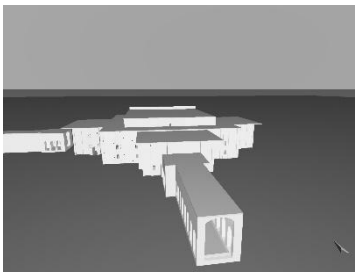
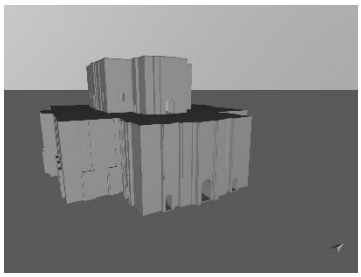
After testing and evaluating several other daylighting software programs, daylighting simulation was conducted for this study using DIALux Evo Software. Table 1 compares the 3D models of Ananda and That-Byin-Nyu temples used in the daylight simulation software, highlighting their geographic coordinates, structural height, and plan views. 3D models of these two historic Buddhist temples are built with proper ambient settings. DIALux Evo is a free planning software that gives access to the features of professional lighting design. It can calculate and visualize illumination for indoor and outdoor locations with DIALux. It assessed the two Bagan temples' daylighting performance. This research, however, is limited to illuminance calculating measures. Some of the essential steps in the simulation for this research are as follows:

- Location and Site Alignment Setting: Before daylight simulation, the site location was Mandalay State, and the model's orientation was chosen correctly. While building a 3D model, it is crucial to add exact opening

sizes to calculate the quantity of daylight entering the building accurately. It is also necessary to include four separate corridor buildings, which are located right in front of the four main entrances in the case study of Temple No.1 The surrounding buildings should also be considered.

- Daylight Calculation: A light scene is needed to perform a daylight calculation. It can be made by choosing a sky condition that has an overcast, average, and clear sky. For direct sunlight, avoid selecting an overcast sky. In this study, clear sky conditions were observed. In the light sense, the preferred date and time can be selected. The critical days of the year, the summer solstice and winter solstice, are generated to calculate the length of the study. For the time selection, 9 am, 12 pm, and 4 pm are chosen according to the opening hours of temples and to collect the changes of sunlight entering the building throughout the day.
- Documentation: This step makes it easy to set up the setting by only choosing the preferred information. It simply contains the information about location, date, time, sky model, and luminance in addition to the photometric data. The selected views in false color rendering have also been added to the summary. The summary always includes the daylight quotient.

Table 1: Case Study Temple 3D Models in Daylight Simulation Software, Dialux Evo (made by the author)

Temple	**Ananda**	**That-Byin-Nyu**
Latitude, Longitude	21°10′14.90″N, 94°52′04.28″E	21.16875°N, 94.86295°E
Height (Max)	51 m (167 ft)	61.3 m (201 ft)
Spire Height	-	66 m (217 ft)
3D Model: Plan View		
3D Model: Isometric View		

4. Results

This chapter includes a comparative study of two selected temples based on case studies and lighting approaches. The investigative study, based on Lechner's (1991-2000) criteria for evaluating lighting design guidelines, serves as a qualitative analysis. While Mukherji (2001) applied this evaluation framework to the study of Hindu temples, this study adapts the same methodology to analyze lighting conditions in Buddhist temples, acknowledging differences in architectural styles and historical contexts. Quantitative analysis includes simulating daylight in both temples using DIALux Evo software.

4.1. Comparative Analysis of Daylighting Technique Inside Bagan Temples (Qualitative Analysis)

The general information about the temples, such as the climate and sky conditions, are the same for both temples since they are located in a closer region of Bagan city, as shown in Table 2. Despite that, the architectural building structure and orientation are not the same, and the daylighting techniques used in ancient Bagan temples are comparable. Table 3 shows a similarity in having main entrances, vestibules, shrines, passageways, clerestory openings, peripheral openings, lateral porches, overhang shading, arches, and finishing. They differ regarding sub-entry, terrace, light wells, and the number of clerestory apertures. The greater the openings and entrance doors, the greater the light achieved inside the buildings. Inside That-Byin-Nyu temple, the distribution of light along the path to the main shrine appears to have been exposed to open air, according to terraces on higher floors.

Table 2: Background Information of The Selected Two Temples with Comparative Analysis (made by the author)

Temple	Ananda	That-Byin-Nyu
Location	Bagan, Myanmar	Bagan, Myanmar
Year/Period	1086AD	1144AD
Built by	King Kyansittha	King Sithu I
Climate	Hot, Humid, Dry Zone	Hot, Humid, Dry Zone
Sky Condition	Overcast	Overcast
Building, Material	One-story brick masonry	five-story brick masonry
Orientation	North, East, South, West	East
Type	Temple with hollow vaulted base	Temple with hollow vaulted base
Function	Meditation, worship, rituals, walking	Meditation, worship, rituals, walking

Table 3: Natural Lighting Technique of The Selected Two Temples with Comparative Analysis (made by the author)

Natural	Lighting Technique	Ananda		That-Byin-Nyu	
Function	Main Entrance	☑	4	☑	2
	Sub-entrance	☒	-	☑	6
	Vestibule/Hall	☑	4	☑	2
	Passage	☑	2	☑	4
	Terrace	☒	-	☑	3
	Main Shrine	☑	4	☑	1
	Sub Shrine	☒	-	☑	3
	> single story	☒	-	☑	4

Opening/ Aperture	Light Well	☑	4	☒	
					
	Clerestory Opening	☑	16	☑	22
					
	Peripheral Opening	☑	24	☑	24
					
	Lateral Porches	☑	8	☑	5
					
	Main Door	☑	4	☑	5
					
Shading overhang		☑		☑	
Arches		☑		☑	
Floor Finishing		cement		cement	
Wall Finishing		White paint		White paint	
Ceiling finishing		White paint		White paint	

4.1.1. Lighting Design Guidelines: Ananda Temple (Qualitative Analysis)

Observation and analysis of Ananda Temple will be investigated based on the following criteria:

- Program: Do not have any specific visual task. To pray and walk (ritual).
- Light and Shadow Distribution: Windows and clerestories are placed in four directions (N, E, S, W). Clerestory windows are positioned high on the walls: six windows and six clerestories on each side. The layout is the cruciform plan, with a double corridor system. Its central square is 53 meters, and gabled porches extend outward from each square's face by 17 meters.
- Direct and Indirect Light: Windows are widely distributed along each wall. The windows and porches are overhang arch-shaped and painted in white. Overhang is a shading device used to filter direct sunlight. The direct sunlight then diffused. In most areas, white paint walls with red paint base, white paint ceiling, gray terracotta floor tile, and some gold paint decoration in image houses along the wall.
- Light Intensity: Clerestories window as horizontal glazing.
- Quality of Light: The direct light from the entrance, lateral porches, and light well along with the diffused light from reflected surfaces. The openings are equally distributed through the wall. Windows and clerestories are high on the wall. Windows are at eye level.
- Visual Hierarchy: The dramatic effect of daylighting by niches and corridors from entry to the inner shrine displays a bright-dark sequence while walking into the inner shrine. Buddha image in the shrine area is highlighted by direct and diffused light from the light well. It appears more contrast because of the low illuminance of surrounding areas.
- Psychological Effects of Light: Direct light enters the vestibule or hall, a welcome area before entering the shrine. Most areas in the innermost shrine are illuminated low, except for the Buddha image. It creates a quality of concentration and ease in closing devotees' eyes when they pray.

4.1.2. Lighting Design Guidelines: That-Byin-Nyu Temple (Qualitative Analysis)

Observation and analysis of That-Byin-Nyu Temple to investigate based on the following criteria.

- Program: Do not have any specific visual task. To pray and walk (ritual).
- Light and Shadow Distribution: Clerestories are placed in four directions (N, E, S, W). However, clerestory windows serve as windows for the upper floors. Clerestory windows are positioned high on walls. Six windows and six clerestories on each side, except the east side has 4. The layout is cubic, connecting with corridors. There are five stories.
- Direct and Indirect Light: Windows are widely distributed along each wall. The windows and porches are overhang arch-shaped and painted in white—overhang as a shading device to filter the direct sunlight. The direct sunlight then diffused. In most areas, white paint on the walls and ceiling, gray terracotta floor tile, cement floor, and some golden Buddha images.
- Light Intensity: Clerestories window as horizontal glazing.
- Quality of Light: The direct light is from the entrance and lateral porches, and diffused light is from reflected surfaces. The openings are equally distributed through the wall. Windows and clerestories are high on the wall. Windows are at eye level.
- Visual Hierarchy: In some places, brightness variations dramatically impact. For instance, a gloomy, narrow stairway reaches a third-floor open-air terrace. Both direct and diffused light highlights the Buddha picture in the shrine area.
- Psychological Effects of Light: The vestibule or hall, which serves as a welcoming space before approaching the shrine, receives direct light. In contrast to the well-lighted entrance, the majority of the sections in the upper shrine area are dimly lit. It creates a quality of concentration and ease in closing devotees' eyes when they pray.

Table 4: Criteria for Evaluation of Lighting Performance in a Comparative Form (made by the author)

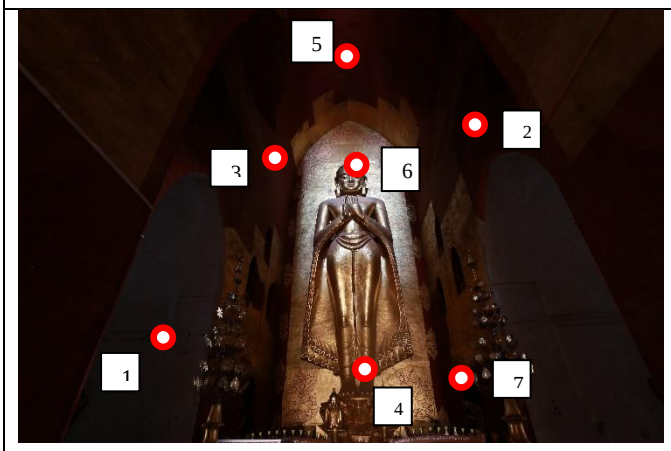
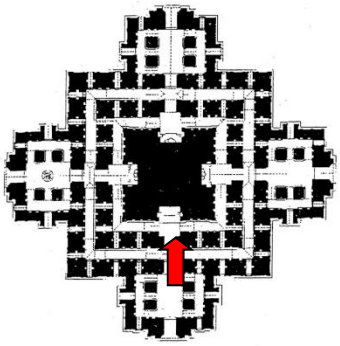
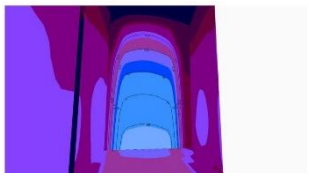
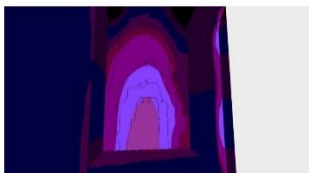
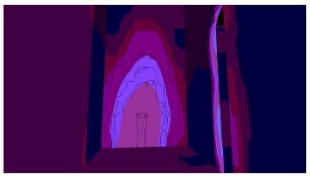
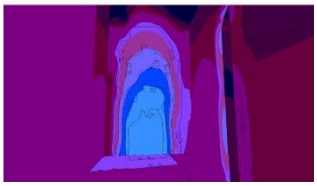
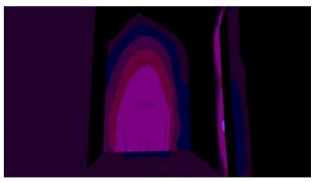
	Design Criteria	**Ananda Temple**			**That-Byin-Nyu Temple**		
		☒	☐	☑	☒	☐	☑
Light and Shadow Distribution	Orientation	☒			☒		
	Position			☑		☐	
	Form	☒			☒		
Direct and Indirect Light	Bilateral Lighting			☑			☑
	Overhang, Shading			☑			☑
	Reflectance		☐				☑
Light intensity	Daylight Control (Opening)		☐			☐	
Quality of Light	Direct & Indirect			☑		☐	
Visual Hierarchy	Dramatic (Darkness)		☐			☐	
	Highlight, Low light			☑		☐	
Psychological Effects of Light	Cheerful			☑			☑
	Personal space			☑		☐	
Total		2	4	7	2	6	4

Based on lighting design standards, Table 4 compares the daylighting system of the two study temples to evaluate how well the lighting design standards are followed (Lechner 1991, 2000). The ratings for the temples are not gratifying as in ☒, moderately fulfilling as in ☐, and entirely fulfilling as in ☑. This numerical ranking aimed to compare the degrees of compliance with the lighting design standards in the two temples. The outcomes of the design guidelines criteria are shown in Table 4. The design standards for both temples are not entirely satisfied. Ananda Temple met 7 of the 12 requirements (58.33%), and That-Byin-Nyu Temple met 4 of the 12 requirements (33.33%). As shown in Table 3, having more numbers of clerestory openings and lower ceilings with multiple floors offer more exposure to sunlight and creates a brighter ambient inside That-Byin-Nyu temple. Ananda temple fulfils higher due to a light well system for additional natural light diffusion, and a serene setting creates private space for meditation. However, the main concept of the dimmest atmosphere at the main shrine area remains the same at both temples despite the construction and natural lighting system changes. Thus, it suggests that religion somehow influences these sacred temples' lighting style and quality.

4.2. Result of Ananda Temple (Quantitative Analysis)

Ananda temple is one of the most famous and ancient temples in old Bagan. The study focuses mainly on the vestibule, shrine, and corridor located on the temple's south side due to maximum sun exposure. There are 5 study points, which are 1) the entrance to the main temple, 2) the vestibules, 3) the main shrine, 4) the southside main corridor view at the east corner, and 5) the southside main corridor view at the west corridor. The temple has a cruciform plan, which is squared-shaped with a measurement of 200 feet on each side. In the vestibule, the study analyzes the south side, which has the most potential for exposure to the sun's direction. At the entrance of the main temple building, which leads to the vestibule or hall, light enters from the main door and lateral porches, while some of the light enters from peripheral windows. Light fraction occurs in the vestibule due to its three-pointed arch ceiling. As a result, less light reaches the depths of the atmosphere because light refracts off the arch ceiling. The lighting distribution at the vestibule is highest at noon during the winter solstice. In all scenarios, it is similar in decreasing the light intensity as passing further from the entrance.

Table 5: Summer and Winter Solstice Render at Viewpoint 3 (Source: Author)

<table>
<tr><td colspan="4">Point 3 - Shrine</td></tr>
<tr><td colspan="2"> 
</td><td colspan="2">  </td></tr>
<tr><td></td><td>9 am</td><td>12 pm</td><td>4 pm</td></tr>
<tr><td>21 June</td><td>  </td><td>  </td><td>  </td></tr>
<tr><td>21 Dec</td><td>  </td><td>  </td><td>  </td></tr>
<tr><td colspan="4"> 
</td></tr>
</table>

When one gets closer to the shrine area where the Buddha statue is, it gets darker and darker. The main corridor to the shrine is narrow and extensive. Due to the depth of niches, a light sequence of bright-dark-bright-dark-darkest is created. Compared to the other areas, the shrine is the deepest and darkest (Table 5). This is the most sacred spot in the temple, where devotees kneel and worship. One might have a sense of freedom in this vertically elevated environment with a pointed ceiling. The Buddha figure is positioned on the other side of the light well, which allows light to penetrate the elevated room. As shown in Table 5, the simulation render shows higher and significant variations in lux levels on the Buddha image inside the central shrine, which creates patterns and contrast, especially at 9 am and 12 pm. According to Hein Min Thaung (2021), the three-square geometrical structure in Ananda Temple serves as a spatial hierarchy that guides movement and the distribution of daylight and serves as a structural framework. Light can enter this system more easily because of the center core's dominance, especially in the direction of the shrine with the Buddha picture. According to this study, the central shrine area has higher lux levels, demonstrating how the temple's architectural geometry controls natural light flow and heightens its spiritual and practical value.

The overall ambient is most lit at noon at winter solstices while the darkest at 4 pm. At 9 am (Fig.2). On the summer solstice, daylight from the light well reaches the lower part of the wall first and then spreads out vertically across most of the wall’s surfaces. In the corridor, one’s eye is drawn to the openings at the end of the extended corridor, wondering what will occur next. Along the way, the clerestory opening lets light in and casts a spotlight on the image house, drawing one's gaze upward to where several images are arranged across the entire wall. The length of the southside corridor is approximately 47 meters, and the distribution of light varies throughout. During the summer

solstice, it is brightest at 9 am. There is a noticeable contrast between different levels of light throughout the day.

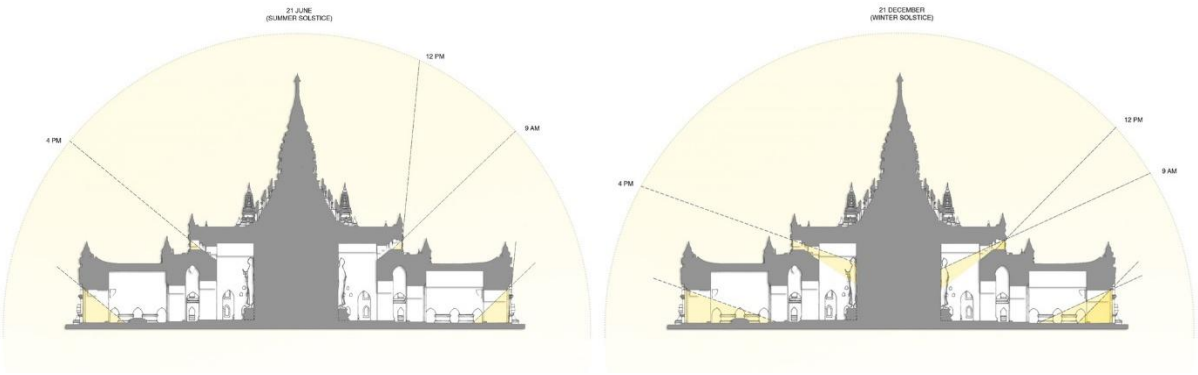
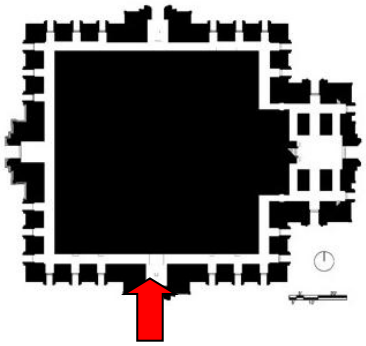
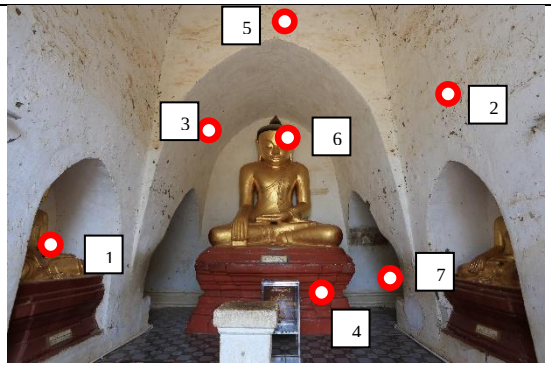
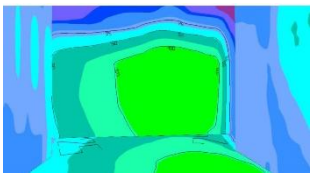
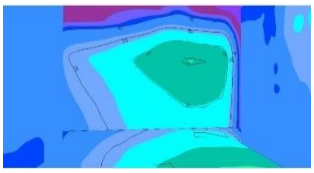
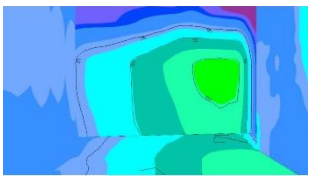
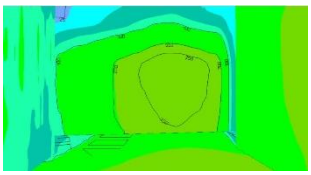
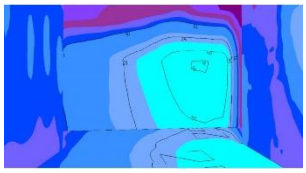


Figure 2: Sunlight At Ananda Temple at Different Time of Summer Solstice (Left) and Winter Solstice (Right) (Redrawn and illustrated by Author)

4.3. Result of That-Byin-Nyu Temple (Quantitative Analysis)

That-Byin-Nyu temple is famously known for its volume. It is only one substantial four-storeyed building in Bagan. The study focuses mainly on the vestibule, shrine, and corridor located on the temple's south side due to maximum sun exposure and the east side main entrance. There are 7 study points, which are 1) the entrance to the main temple, 2) the vestibules, 3) the corridor beside the vestibule, 4) the corridor facing south, 5) the southside main corridor view at the east corner, 6) the southside sub-shrine and 7) the southside corridor view at the west corner. Because of its different layout plan, this temple has more study points than Ananda temple. However, studying the south side corridors and the route from the main entrance to the shrine serves the same objective in both temples. The temple has a square plan of approximately 62 meters in length on all sides, excluding a slightly extended entrance hall at the east axis. The ceiling of the vestibules is a three-pointed arch, and it causes light refraction. This room has three lateral porches on each side leading to this level's corridor. Despite the volume of the building, the interior of the vestibule is relatively tiny and enough lit. At both the summer and winter solstices, the light is uniformly dispersed and at its peak intensity at nine in the morning. Standing at the entrance and allowing one's eye to adjust to the dim lighting inside the inner shrine will help. More sunlight enters through the floor and bottom portion of the wall than via the top wall and arch ceiling.

Table 6: Summer and Winter Solstice Render at Viewpoint 6 (made by the author)

Point 6 – Southside Sub-Shrine			
			
	9 am	12 pm	4 pm
21 June			
21 Dec			
			

The sub-shrine double-height ceiling allows a lot of natural light to enter the room (Table 6). White paint was used for the ceiling and wall finishes, making the space more luminous. The Buddha picture with the gold paint has the most reflective surfaces in the space. The daylighting in this sub-shrine is evenly dispersed and well-lighted, in contrast to the shrine on the fourth floor and the main shrine in Ananda Temple. As shown in Table 6, the simulation render shows higher lux levels at every side of the room, which creates no significant contrast, unlike Ananda Temple.

At the winter solstices, the light is most potent at noon (Fig.3). Due to the room's homogenous illumination, there is no apparent contrast inside this sub-shrine. This temple has one corridor system on the ground floor and fourth floor and a double corridor system, like in Ananda temple, on the second floor. The corridor is used to connect around the shrine. The viewpoints on corridors studied in this temple are those beside the vestibule, southeast, and southwest. The sunlight from porches cast a spotlight on the floor and wall and diffused onto half of the arch ceiling. This concept of light started to be noticed due to the low-lit ambient in this narrow corridor. The intention of placing an eye-level porch at the turning point of the corridor is appealing to encourage continuing the walk and give a sense of a way to the light. This monument, which was constructed during the Bagan era's inventive time, combines new and old building techniques to produce vertically expanded several floors. This enables the inner space to have additional uses and human activities. The temple is well-lit, has more extensive internal areas, and has an unpredictable lighting sequence that changes from the ground to the upper floors. Even though the main shrine is located on higher floors, it still maintains the concept of gloom and low illumination at the innermost shrine, followed by a uniformly well-lit vestibule and connecting hallways.

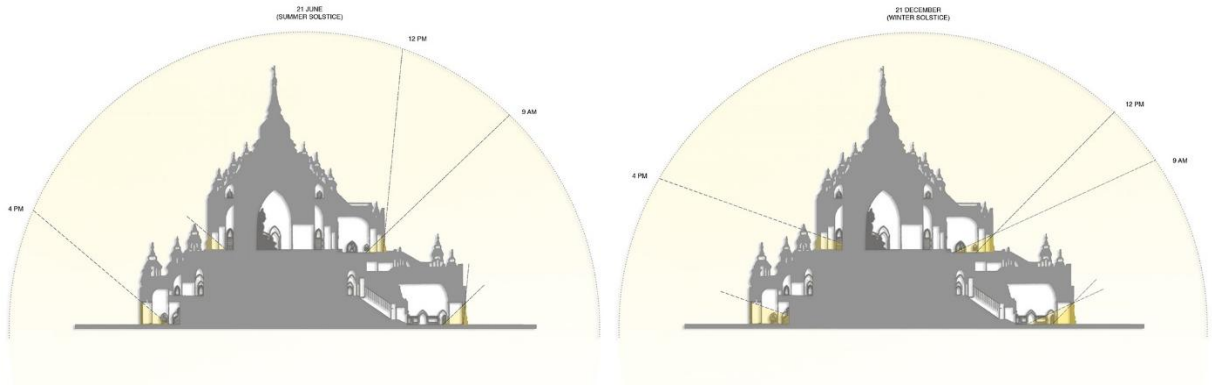


Figure 3: Sunlight At That-Byin-Nyu Temple at Different Time of Summer Solstice (Left) and Winter Solstice (Right) (Redrawn and illustrated by Author)

5. Discussion and Conclusion

5.1. Discussion

The findings highlight how daylighting in Bagan's sacred architecture was deliberately designed to enhance both spatial function and spiritual experience. When the lighting strategies in the two temples are compared in terms of achieving daylight performance criteria, it is apparent that Ananda temple has a more controlled daylighting system enhancing contrast and spiritual quality of light. The that-Byin-Nyu temple has a brighter ambience due to its numerous openings. The variations in daylight performance between the two temples stemmed from different daylight design principles and architectural modifications. These temples differ in the concept of perceiving light, the form of the building, the location of the main shrine, the number of openings, and the position of it.

Nevertheless, the darkened ambience in their main shrine is comparable to that of these temples. When there is no opening or light well, it enables less exposure to light and less visibility to the outside world. Devotees enter this location, form a praying posture, close their eyes, and worship. This daylighting strategy finds parallels in Hindu temple architecture, where Mukherji (2001) observed a gradual transition from bright entrance areas to darker inner sanctuaries. This technique served spiritual and climatic purposes, enhancing worshippers' focus during meditation and maintaining thermal comfort in hot, humid climates through limited openings (Mukherji, 2001). Material choices further differentiate the two traditions. While Buddhist temples in Bagan use reflective surfaces or, commonly, white paints to enhance daylight diffusion, Hindu temples' dark interiors are made of granite stone construction with limited openings. Moreover, Hindu temple layouts emphasize darkness, whereas Buddhist temples use clerestory and peripheral openings for dynamic play of light and shadow. This comparison highlights how religion influences architectural lighting strategies across different traditions.

Direct sunlight's role was also examined during important solar events, such as the summer and winter solstices. Except for That-Byin-Nyu's ground-floor sub-shrine, where solar exposure is more noticeable, the analysis shows that direct sunlight rarely reaches the vestibule floors during the summer solstice, limiting overheating in gathering areas. Nearly half of the vestibule areas in both temples are lit by direct sunlight during the winter, and the light well at Ananda Temple allows concentrated sunlight to be directed onto the Buddha image at particular times, thus enhancing the temple's spiritual purpose. These findings highlight how daylight was an essential component of sacred symbolism and worship rituals in Bagan's Buddhist architecture and a useful design feature.

5.2. Conclusion

This study highlights the significant role of natural light in shaping the spiritual experience of sacred architecture. Ancient Bagan temples utilize natural lighting systems for religious activities and faith growth. These monuments showcase technology, architecture, and human-space relationships, highlighting the importance of user relationships with space. Designing a space of great function can be done by understanding how the built environment affects human behavior, specifically regarding human cognition and feeling (Banaei, Hatami, Yazdanfar, & Gramann, 2017).

This study achieved the aims of studying the role of religion in the lighting treatment of a sacred monument and investigating the daylighting performance of the main shrine and corridors at two temples by conducting qualitative and quantitative research. The research suggests that modern artificial lighting systems in Bagan temples fail to preserve the original spiritual and spatial experience, diminishing the intended sensory impact of natural light. Future studies should explore how modern artificial lighting applications can be designed to mimic the rhythm and quality of daylight while maintaining the spiritual quality of ancient Bagan temples. By understanding the relationship between light, space, and spirituality, architects and conservationists can develop lighting solutions that preserve the integrity of historic temples while adapting to contemporary needs.

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Ethics Approval

Not applicable.

Conflict of interest

The authors declare there is no conflict.

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