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RECREATING THE TIBETAN TRADITIONAL LIGHTING IN LOCAL MODERN LIBRARY: RESEARCH-BASED LIGHTING DESIGN IN YUSHU LIBRARY

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ABSTRACT

This paper demonstrates the research-based lighting design process of Yushu Library, a new library built after the 2010 Yushu Earthquake. The design goal is to recreate the Tibetan traditional lighting in this local modern library without sacrificing functional needs. The research methodology is comprised of a literature review, site visit and measurement, user interview, and daylighting simulation.

Keywords: lighting design, Tibetan traditional architecture, lighting evaluation, daylighting simulation

1. PROJECT BACKGROUND

1.1. Post-Earthquake Reconstruction

The 2010 Yushu Earthquake registered a magnitude of 6.9 Mw and originated in Yushu Tibetan Autonomous Prefecture, Qinghai Province, China. Over 85 % of buildings in Gyegu, the seat of Yushu County, were destroyed. The post-earthquake reconstruction plan included a library, a theatre, a cinema, and a cultural centre. Yushu Library was designed and built serving as the core project in rebuilding the town and community after earthquake [1].

1.2. Unique Traditional Architectural Lighting

In China, Yushu is in Lighting Climate Zone I, which has an average daylight illuminance of 28,000 lx [2]. At an elevation of 3,700 meters, Yushu has a harsh alpine subarctic climate with 2496 sunshine hours annually. The sunshine hour was defined as the period, during which direct solar irradiance exceeds a threshold value of 120 W/m^2 [3]. The cold climate, the large temperature difference between day and night, and strong ultraviolet radiation have historically led to an inward architectural form with small windows and thick walls to prevent heat loss and an atrium to get an access to daylight in public buildings [4].

This traditional architecture form creates a unique lighting, which is experienced daily by local residents, 97 % of whom are Tibetan and have Tibetan culture deeply rooted in their daily life. The new Yushu Library is designed for the local users to enjoy a modern library, which embodies a traditional Tibetan architectural environment through space geometry, interior furnishings, and lighting. This is a library in Yushu and for Yushu and would not be the same as a library in Beijing, New York, or London.

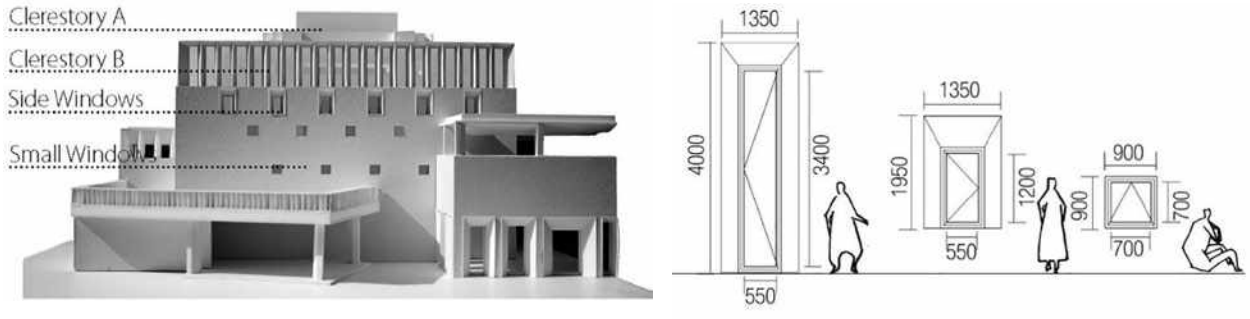

Fig. 1. Yushu Library physical model and window system

1.3. A Current Design Problem

The obvious difference between new and traditional architectural lighting is a rising issue in Yushu post-earthquake reconstruction projects. New public buildings kept traditional space form and decoration style, but their lighting directly followed the national standards in China [5, 6]. By simply following the standards, designers on some projects introduced excess daylight or electrical lighting into new buildings. This increased the illuminance level and decreased the luminance contrast, which is on the contrary of Tibetan traditional lighting.

For electrical light, the standard [6] requires 300 lx for library reading rooms. According to the recommended light levels from the IESNA Lighting Handbook [7], the light level in a Library – Reading / Studying is (300–500) lx. For daylight, the standard [5] requires minimum 2 % Daylight Factor for library reading rooms. In [8], Section 2.2.2.1, it states that "An average daylight factor below 2 % generally makes a room look dull; electric lighting is likely to be in frequent use." [5] is aligned with [8].

If the characteristics of a traditional lighting could be quantified, could a new lighting be designed to resonate with traditional lighting? This is the question we asked in the beginning of this research-based design.

2. CONNECTION BETWEEN THE NEW LIBRARY AND THE TRADITIONAL CHANTING HALL

2.1. Yushu Library

Yushu Library has four floors with a gross area of 4300 m² (Fig. 1). Architects learnt from traditional Tibetan architecture and kept the architectural elements including small windows and atrium, which provided a solid foundation of further design to recreate traditional lighting. The window size increases from the bottom to the top, and the atrium is the library core space with a clerestory as the main daylight path. There are 3 reading programs in the library (Table 1).

2.2. Case Selection on Traditional Tibetan Lighting

Traditional Tibetan architecture is a broad definition, which includes public religious buildings and private residential buildings, among which Tibetan Buddhist monastery buildings are the most well-studied type. Monasteries concentrate religious consciousness, aesthetic concept, local context, and advanced building technology for the time [4]. Among Tibetan Buddhist monastery buildings, a Chanting Hall is a significant public venue for religious activities and events, where monks read daily and villagers read during religious events. The visual tasks in a chanting hall are similar to the ones performed in a library by users. The chanting central area is similar to the atrium in Yushu Library in terms of function and space geometry.

The traditional Tibetan lighting is a result of how architecture responds to local climate and cultural context. Small windows in thick walls, a clerestory for daylight access, high luminance contrast, low average illuminance, and dark areas shape the lighting in a traditional Tibetan building. The daylight path of a typical chanting hall is distinctive. In most of the chanting halls, the clerestory around the lifted roof is the daylight path for chanting area.

The Damkar Main Chanting Hall is located at the Damkar Monastery, which was initially built in about 1190 (the Song Dynasty) and has been used for local religious events and daily chanting since

Table 1. Reading Programs in Yushu Library

Reading Area	Number of seats	Daylight Source	Can daylight achieve 300 lx standard?
Atrium centre	24	atrium clerestory	No
Around atrium	72	atrium clerestory	No
Wall niche	76	side windows	Yes

then. The Main Chanting Hall and Yushu Library have similar visual tasks and daylight path. Site visit, measurement, interview, and simulation were performed to evaluate lighting of the Damkar Main Chanting Hall.

3. METHODOLOGY: THE BRIDGE FROM RESEARCH TO DESIGN PRACTICE

The project goal is recreating the traditional lighting in the new library via evaluating the lighting in both the traditional chanting hall and the new library. The methodology has been developed for general instances, in which local traditional context and elements are valued by both users and designers of the new buildings. The methodology layout is:

a) Quantify the local traditional daylighting through simulation and field measurement;

b) Transfer the traditional daylighting into the new building and fulfil the light level requirement in a modern library;

c) Evaluate the design environment in the library through simulations on both daylight and electrical light, and adjust the furniture layout, interior material, and fixture control schedule to achieve the designed effect and reduce energy consumption.

The methodology guides research steps and design actions in order to apply research discoveries in design practice. Fig. 2 maps the integration of research and lighting design.

4. LIGHTING RESEARCH FOR MAIN CHANTING HALL

4.1. Objects of Study

Yushu Library has an atrium with four floors, but by the current lighting standards, daylight only cannot provide enough illuminance for the ground floor reading area. Electrical lighting is needed as a supplement to daylight during open hours. The object of research is the atrium space (Fig. 3) (Table 2).

The models of the Main Chanting Hall and Yushu Library were built in Rhinoceros based on building measurements and drawings and calibrated with field measurements.

4.2. Field Measurement and User Interview

Field measurements taken in the Main Chanting Hall included Daylight Factor (DF), material reflectance and transparency, and a close observation of user behaviour. DF was measured for further calibration of model simulation result, since the digital model was simplified by excluding decoration and structure details. Material reflectance was measured by spectrophotometer, which provided material parameters in the simulation.

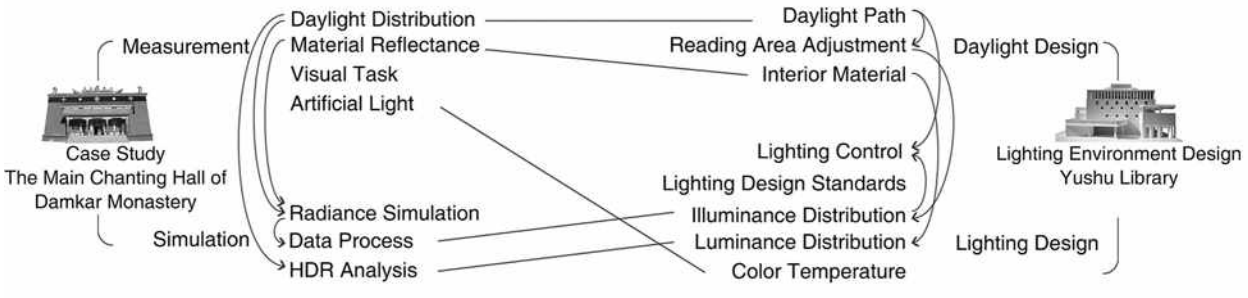

Fig. 2. Methodology map of research-based design

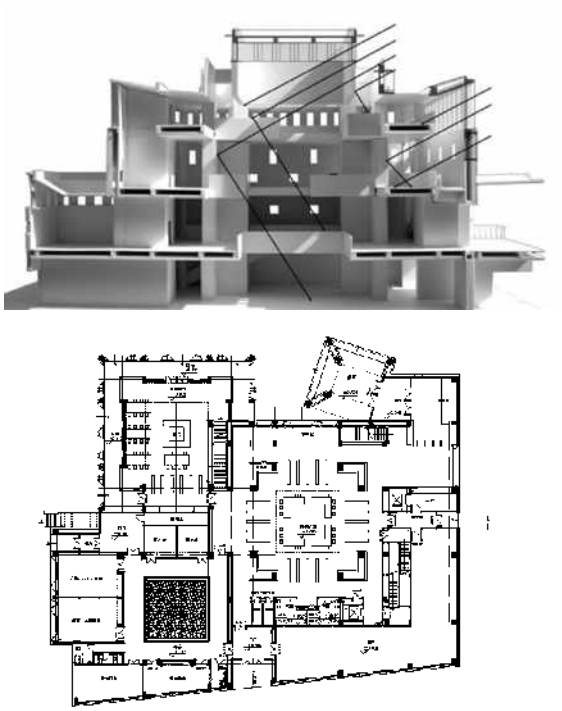

Fig. 3. Yushu Library section, first floor plan, and daylight path

The average DF in the Main Chanting Hall is 0.22 %, and the standard-required minimum DF for library reading rooms is 2 % [5]. However, the monks use the centre of the atrium for chanting, where the daylight condition is the best with direct sunlight. The chanting time is when direct sunlight reaches the centre of the atrium. The illuminance of the reading area could achieve 200 lx at noon on a sunny day. When it gets dark in the afternoon, the main tasks are cleaning and maintenance. Fig. 4 shows the daylighting difference between

Fig. 5. Chanting material and typical chanting position in the Main Chanting Hall

Fig. 4. 12:00 pm (*a*) and 4:00 pm (*b*) at the Main Chanting Hall (December 8, 2012)

chanting time and maintenance time in a day. It also revealed the limitation of DF as an indicator of daylight availability.

Observation and interview of users (15 monks as daily users) provided first-hand information on how users react to lighting. All interviewees said the daylight was enough for chanting. While chanting, monks sit on seats that are 400 mm tall. All words are in Tibetan Uchen script in about size 11, and the reflectance of the paper is 0.91 (Fig. 5).

4.3. Daylight Autonomy and Illuminance Pattern

Diva for Rhino was used in the simulation for annual daylight evaluation in the Main Chanting Hall. The calculation of annual daylight autonomy (DA) was based on the local weather data from EnergyPlus weather file of Yushu, Qinghai [9]. Annual daylight autonomy takes the local climate into consideration, which is critical to this project: the local climate provides generous sunlight almost all the year, which shaped the unique architectural space and its lighting. For DA (50 lx), only the centre of the atrium, where monks sit and chant, has a higher daylight autonomy of 50 %. The perimeter along the wall is the dark area with only 10 % daylight autonomy, but it is only used for circulation.

In Fig. 6, annual daylight autonomy revealed that the large cloth decorations in the Main Chanting Hall played an important role in reflecting direct sunlight from the south-facing clerestory, to provide an even and bright reading area in the centre.

For quantifying daylight information, the chanting hours on typical days were taken as study hours: 9 am to 12 pm on March 20–22, June 20–22,

Table 2. Comparison of Main Chanting Hall and Yushu Library on Building Definition

Building	Main Chanting Hall	Yushu Library
Location	33°0' N97°8' E	33°0' N97°0' E
Year of built	1190, 1981 (rebuilt)	2012
Floor	4	4
Ground floor atrium area	633 m^2	784 m^2
Ground floor seats	24	24
Users	Monks and local residents	Monks and local residents

September 20–22, and December 20–22. The accumulated illuminance of each point during the study hours was from the data file generated by the annual daylight autonomy simulation. The accumulated illuminance of chanting hours on those sample days was used to extract daylight illuminance pattern. On the horizontal surface, the average accumulated illuminance of each area was the average of 9 test points in the Reading area (R) and 30 test points in the Circulation area (C). Accumulated daylight illuminance ratio of R: C is from 8.5:1 to 10:1.

On the vertical surface the average accumulated illuminance of each area was the average of 4 test points in the Top area (T), 4 test points in the Clerestory area (C), and 4 test points of the Bottom area (B). The Clerestory area was affected by direct sunlight, so the ratio was not constant. Accumulated daylight illuminance ratio of T: B is from 4:1 to 6:1.

These illuminance ratios of the Main Chanting Hall were used as references for the illuminance ratio of the Yushu Library.

4.4. HDR Analysis and Luminance Pattern

HDR (High Dynamic Range) analysis was applied in the luminance analysis in the Main Chanting Hall. In HDR photos of the Main Chanting Hall clerestory, the ceilings and cloth decorations had the highest luminance, while the wall of the circulation area has the lowest luminance. In HDR photos of the Main Chanting Hall atrium, the Buddha statue has the highest luminance level. Monks that sit nearer to the Buddha statue have higher luminance on their faces. The ratio of luminance on the main surfaces is shown in Fig. 7. These luminance patterns were used as luminance reference for lighting design of Yushu Library.

5. LIGHTING DESIGN PROCESS

Architects rely on space geometry and furniture finishing to express local context. Lighting designers rely on the combination of daylight and electrical lighting to achieve the same goal. The traditional Tibetan lighting of the Main Chanting Hall is the basis for lighting design of Yushu Library (Table 3).

After quantifying the daylight illuminance and luminance pattern in the Main Chanting Hall, the lighting design process began with a concept and went through inter-disciplinary coordination, fixture selection, and installation. It was finished with on-site adjustment to demonstrate the found patterns while fulfilling the lighting design code requirements. After designing based on the illuminance and luminance pattern from Main Chanting Hall, Dialux was used for testing illuminance and lumi-

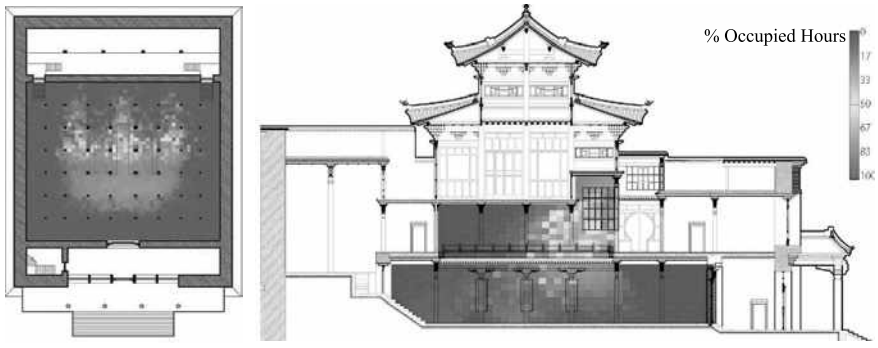

Fig. 6. Daylight distribution on horizontal surface (DA 50 lx) and vertical surface (DA 100 lx)

Table 3. The Relationship between Daylight and Electrical Light for Both the Main Chanting Hall and Yushu Library

	Daylight		Electrical Light	
	Research on the Main Chanting Hall	**Design for Yushu Library**	**Research on the Main Chanting Hall**	**Design for Yushu Library**
Space Geometry and Daylight Path	High atrium with clerestory, small side windows	High atrium with clerestory, small side windows	N/A	N/A
Reading Area and Daylight	Sitting area in the center of the atrium (best daylight autonomy area)	Revise the seating area based on daylight autonomy simulation	Monks use candle or LED lamp with battery pack at night.	Supplement of electrical task light at seat
Work Plane Illuminance	Measured 200 lx during chanting time (average of illuminance at 24 chanting seats)	Standard 300 lx	Candles are lit along the statues, not intended for reading	Supplement of electrical light to reach to the illuminance level required by the standards
Reading Time	9:00 am – 5:00 pm	9 am – 12 pm in summer; 9:30 am – 12:30 pm in winter	N/A	N/A
Visual elements (luminance ratio)	Clerestory, ceiling, and floor illuminance ratio 40:2:1	Revised wall material to adjust the reflectance	N/A	Enhanced clerestory illuminance

nance level of the library with the lighting design plan and selected lighting fixtures to test and adjust the lighting design.

Based on the result of electrical lighting simulation, the illuminance ratio of the reading area and the circulation area in the Yushu Library was 6:1. During daytime with daylight from the atrium, this ratio would increase, closer to the ratio in the Main Chanting Hall (from 8.5:1 to 10:1). Both the reading and the corridor area illuminance fulfilled the illumination requirements (300 lx and 100 lx). For vertical surfaces, the illuminance ratio of the ceiling and floor areas was 4:1, which was close to the ratio in the Main Chanting Hall (from 4:1 to 6:1). The simulated luminance condition in Yushu Library has a similar pattern with the HDR luminance condition in the Main Chanting Hall.

Yushu Library was opened to local residents and monks in December 2013. Fig. 8 shows the daylighting in the Yushu Library.

6. CONCLUSION AND DISCUSSION

The reproduction of traditional lighting in a new building is achieved based on close collaboration with architects through creating similar lighting distributions, revising the daylight path, adjusting key surface reflectance, and changing reading area locations. However, the eyes of the users are used to new visual tasks, some of which did not exist when the traditional buildings were built, such as reading on computer screens. Further discussion on the suitability of this methodology from traditional lighting to modern lighting design is needed for these new visual functions.

In the early phase of design, lighting designer, architect, and the client had a discussion over the possible glare control and daylight harvesting. However, first of all, the budget for this project is limited due to the limited total funding for all reconstruction projects in Yushu after the catastrophic earthquake. Electrical shades or dimmable lighting fixture controlled by daylight sensors are out of question due to the low budget. Second, local users are in fond of sunlight. During interviews with local monks at the Damka Monastery, we found the direct sunlight went through the clerestory and shine upon the reading area in chanting hours. Most users found direct sunlight provided the connection between interior artificial environment and exterior natural environment. Third, this library has 172 seats available around the atrium and facade with

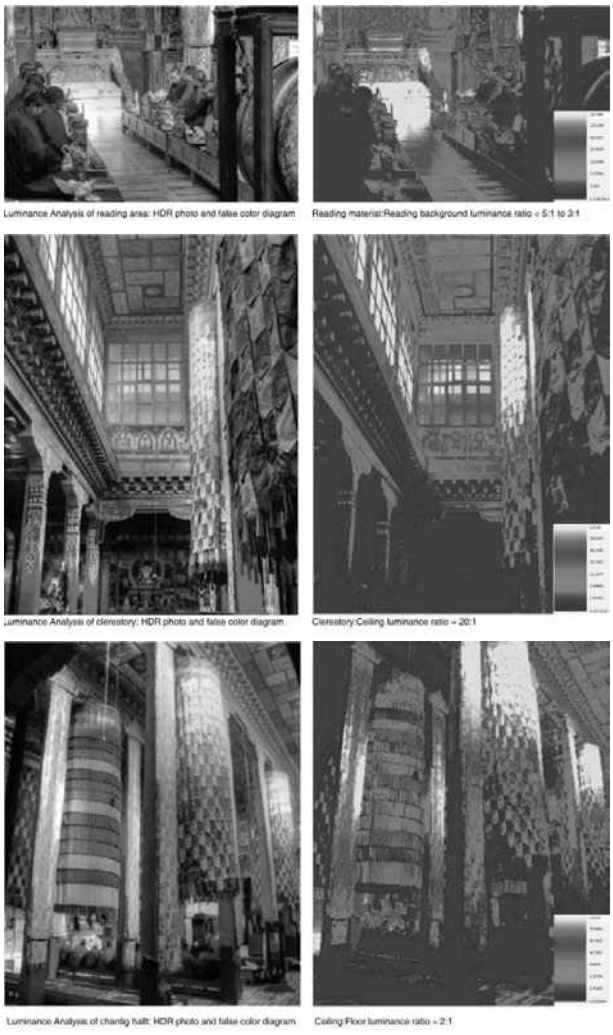

Fig. 7. HDR analysis on luminance in the Main Chanting Hall

daylight access. Compared with the number of daily users there are always seats available if one area is subject to severe glare.

The quantitative study of traditional lighting provides a solid base of design with comparable and quantified criteria such as illuminance and luminance. A multi-tool based methodology was developed and tested to achieve the best performance of lighting in the new library. Daylight only, in this library, cannot fulfil the modern requirement for reading. Introducing electrical light can provide much flexible time and location for the reading tasks. HDR analysis is close to what people see, but it was an instantaneous record: typical conditions have to be chosen carefully to represent the actual condition in a year. However, introducing electrical light will also raise the concern on sacrificing traditional lighting. Careless accommodation of daylight and dependence on artificial light could lead to the

Fig. 8. Photos of Yushu Library (Credit: Rui Zeng)

loss of the traditional environment in a building. It was also the trigger of the research and practice on this methodology. All front of house electrical lighting fixtures are with >80 CRI LED or fluorescent source. Atrium and reading areas are utilizing 3000K colour temperature to provide the warm white light. At the perimeter of clerestory, 4000K colour temperature light is used to wash the vertical surface below clerestory, to form the contrast between reading area and clerestory, and to echo the cold white tune from the skylight.

Back in 2012 when the daylight simulation for this project was conducted, Daylight Factor was the only parameter for daylight evaluation in standards for China, while further evaluation parameters were not included in standards or recommendations in other countries. However, Daylight Factor is not utilized in prevailing standards now (2018). IESNA has published a standard on approved method [9]. Some established and much-used methods of certifying the sustainability of buildings, such as LEED (Leadership in Energy and Environmental Design), makes recommendations for daylight. According to [10], it is required to achieve a Spatial Daylight Autonomy (sDA 300 lx, 50 %) in 55 % (2 pts) or 75 % (3 pts) with Annual Sunlight Exposure (ASE1000 lx, 250 h) below 10 % in all regularly occupied floor areas to earn the Daylight Credit.

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