Materials Science Forum
ISSN: 1662-9752, Vol. 980, pp 223-230
doi:10.4028/www.scientific.net/MSF.980.223

Submitted: 2019-07-29
Revised: 2019-08-05
Accepted: 2019-08-09
Online: 2020-03-06

Analysis of Building Construction Materials and Environmental Technology of Labrang Monastery

Qi Gao[1,a*], Xiangwu Meng[2,b], Daiwei Luo[3,c] and J.W.R. Whitehand[4,d]

[1]Weifang University, Weifang, 261000, China

[2]LanZhou University Of Technology, 730000, China

[3]Suzhou University of Science and Technology, 215011, China

[4]University of Birmingham, B15 2TT, United Kingdom

[a]564048577@qq.com/wfxygq@wfu.edu.cn, [b]84666097@qq.com, [c]441322693@qq.com, [d]Whoisldw@gmail.com

Keywords: Tibetan Buddhist monastery; Labrang Monastery; Building construction; Building materials; Building environment technology

Abstract. Labrang Monastery is the only main monastery of the Gelug Sect of Tibetan Buddhism in Gannan area. From the perspective of building materials and technology, this paper carries out literature research and fieldwork in order to comb and summarize the main construction of monastery buildings and common building materials. Furthermore, it systematically analyses the architectural phisics, (acoustics, optics and thermotics) of monastery buildings via methods such as research, servey and data analysis. These above have positive referential value for the protection and renovation of Labrang Monastery and the modern design of regional religious buildings as well.

With the background of "One Belt and One Road" macro policy, the development of Labrang Monastery is confronted with new challenges and opportunities as a typical representative of religious buildings in Gannan area. It needs the solid basic of systematical study to explore how to protect and inherit regional architectural features and how to avoid the influence of cultural convergence.

At present, the research results of Labrang Monastery abroad are relatively few, and mainly are from the religious and sociological perspectives, focusing on the interpretation of Sino-Tibetan relations, politicians and religious figures, as well as customs and cultures, rarely involving the Labrang Monastery the building itself[1-3]; Correspondingly, the domestic research is relatively rich, among which the research on the field of architecture mainly focuses on monastery morphology architectural space layout, architectural style, architectural art and architectural culture, while as for construction, or other aspects of the Labrang Monastery building materials, construction and physical environment technology research are not systematic, with only a few buildings once mentioned about. Labrang Monastery is a typical representative of Tibetan Buddhist architecture, which is well preserved. From the perspective of materials and environmental technology, it has positive significance for deepening the protection and inheritance system.

1.General Introduction of Labrang Monastery

Labrang Monastery was built in the reign of Kangxi in the Qing Dynasty (1708 A.D.)[4]. It is located on the west side of Xiahe County, which belongs to Gansu Province. Labrang Monastery is located near the base of Tea-Horse Trade. Under the influence of multi-culture, the monastery shows strong regional characteristics[5]. At present, the monastery is the key cultural relic protection unit in China and it is also one of the most perfect Tibetan Buddhism teaching system[6].

The whole monastery is facing south, surrounded by mountains and rivers which is very magnificent (Fig. 1). The north side of the monastery is Woxiang Mountain, and the south side is adjacent to Daxia River. The monastery covers an area of 866,000 square meters, composing 6 Sutra halls, 16 Buddhist temples and 28 living Buddha palaces. In addition, there are a large number of adjunct buildings such as lecture platform, monk's house and so on. Architecture layout conforms to

the terrain, arranged according to different levels, architectural style has Tibetan and Han-Tibetan combination, architectural form belongs to the typical Gelug model of Tibetan Buddhism.

Fig.1 Scene of Labrang Monastery

2.Architectural Construction and Materials

2.1 Architectural construction

The architectural construction of Labrang Monastery mainly includes 2 parts: walls and roofs. The wall part focus on the construction of stone wall and dashphora wall and the roof part mainly refers to Tibetan-style roof construction.

2.1.1 Wall construction

(1) the flake-stone wall construction.

Walls of stone are usually used in buildings of Labrang Monastery no matter in the Tibetan-style buildings or the Sino-Tibetan style buildings, and the flake stone walls have the supporting function as well. To the stone wall, its construction starts from the top of the base of the wall foundation, and the bottom of the foundation is tamped with silty clay. After Tamping, the foundation groove is built with stone and loess mud, and filled with gravel and mud. The foundation groove is built to the ground, and then the stone wall continues to be built up. The bottom layer of the wall is 1.5-2 meters thick. The inner and outer surfaces of the wall are made of flat Piece of stone, and the interior is filled with irregular slabs that are superimposed on each other. Repeated masonry like this, the stones overlap each other by 1/3. The thickness of the wall is thicker at the bottom, but getting gradually thinner to the top. From the wall profile, it can be more clearly seen that the inner side of the wall remains vertical and the outer side is inclined, which the angle of contraction is generally 6-7 degrees. When laying a wall of two or more layers, the upper wall is still thinner than the lower layer, and there is a pulling back on the outside as well. The bonding material of the stone is the local black soil, which is mixed into slurry. The outer surface of the wall is painted white, red or yellow, according to the building facade, and the inner surface is generally painted white. (Fig.2)

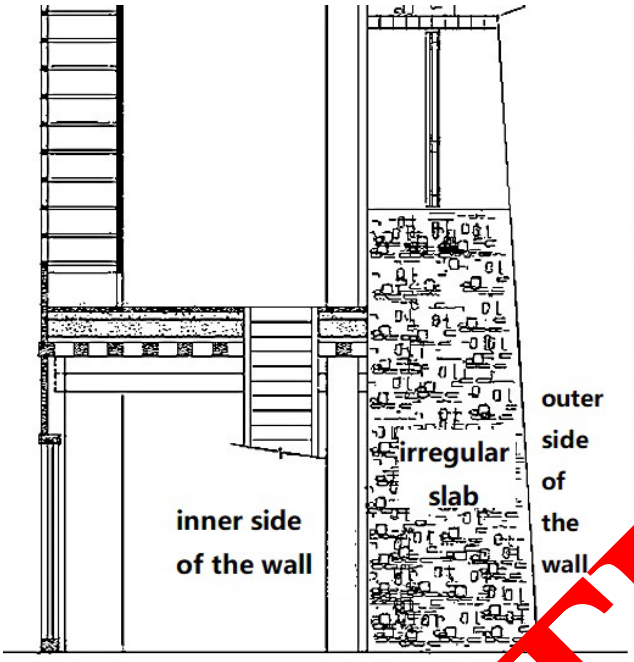

Fig.2 The stone wall construction

In addition to the flake-stone walls, many buildings of Labrang Monastery use rammed soil walls and brick walls. The rammed soil walls are generally used in walls of courtyard and walls of Monk houses. The rammed soil walls in Labrang Monastery use the yellow sandstone soil of Xiahe County, and the thickness of the wall is generally between 0.5-0.8 m. In terms of color, the inner and outer sides of rammed soil walls are painted into white and or yellow (Fig. 3). Besides, the brick wall can be found in the Han-style sleeping palace of Jiamyang. The wall is made of black brick, and its construction is from the Han-style of Qing Dynasty (Figure 4)

Fig.3 Rammed soil wall

Fig.4 Brick wall

(2) the dasiphora wall construction.

The dasiphora wall is a decorative part on the important buildings of the Labrang Monastery. They're usually used on the exterior walls, with the function of anti-theft and protecting the walls from being washed away by rain. The dasiphora walls are usually painted in red. The dasiphora wall of the border is to bundle the red wicker into small bundles, dyed brown, dark brown and then cut, and the roots are densely arranged on the wall (Fig. 5). The upper and lower sides of the dasiphora wall are covered with decorative wooden strips and small picking heads. The wooden strips have vertical rods, and the middle is fixed with vertical wooden strips. Add a horizontal tiebeam on the top and bottom of the dasiphora wall, and a row of short woods is laid under the top and bottom tiebeam（Fig. 6). The

construction of the entablature is to placing slab on the tiebeam to make the cornice. The dasiphora wall is decorated with gilded bronze plates which has patterns of Buddhist and Sanskrit[8]. The construction of a dasiphora wall from the bottom is "square rafter - tiebeam - slab– dasiphora tied up with string - tiebeam – rafter - copestone" in proper sequences (Figure 7).

Fig.5 The dasiphora bundled and placed on the wall

Fig.6 Finished dasiphora wall

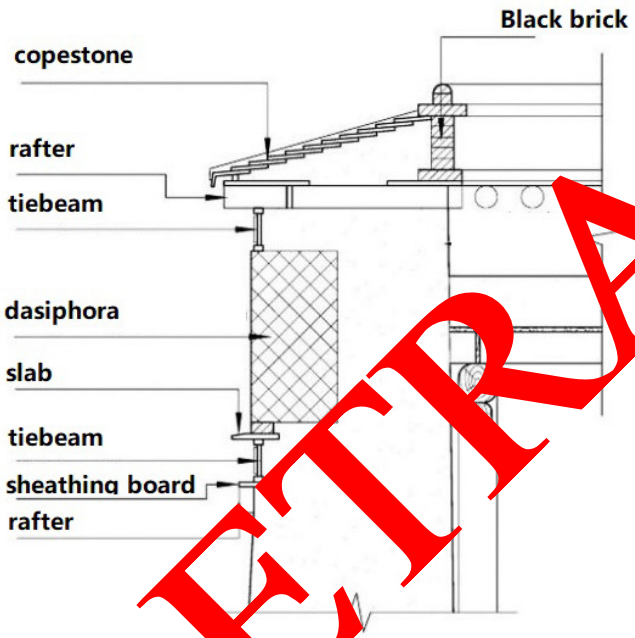

Fig.7 The dasiphora wall construction

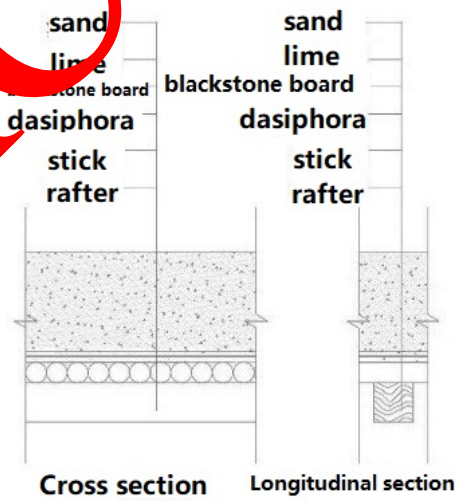

Fig.8 The Tibetan-style roof construction

2.1.2 Roof construction

The Tibetan-style roof construction of the Labrang Monastery (Fig. 8) can be divided into six layers. From bottom to top, it is wood rafters, sticks, dasiphora, blackstone boards, lime and sand. In comparison, the thickness of the sand layer is relatively thick, generally between 45cm and 55cm. There is a scattered water slope in the sand layer, and the slope of the scattered water is generally 2%. This construction is relatively simple and cheap, so it is widely used in the roof construction of Labrang Monastery.

2.2 Building Materials

The building materials used in the monastery mainly include soil, stone and wood, according to the research.

(1) Material of soil

According to the investigation, the soil used in buildings can be divided into black soil, loess and yellow-sand-stone-soil, which are all from the local site. The black soil is generally used as bonding

material due to its good adhesion ability, and it needs to be soaked with water before use. Because of the soft texture, the loess is usually applied to the inner walls of the building for drawing murals, but it is usually mixed with a certain proportion of fine sand to use. The yellow-sand-stone-soil is often used as the roof material. The general construction is to lay a branch of about 50cm on the rafter of the roof, then make a layer of cobblestone about 60cm thickness above[9]. The craftsmen filled the gap with black soil and made the layer of black soil's thickness up to 50cm, then filled the yellow-sand-stone-soil on it and continue to tamp. (Fig.9).

Fig.9 Roll-over tool of roof

Fig. 10 Stone at the bottom of the wall

(2)Material of stone

The construction of Labrang Monastery uses a large amount of stone as the material of load-bearing system. It is generally divided into two types: block stones and schistous rocks. The normal size of block stone is 17cm*23cm*35cm. The thickness of schistous rocks is usually 2~3cm, which is used to level or to fill the gap of block stone. (Fig.

(3)Material of wood

The interior construction of Labrang Monastery is mainly made of wood. Wood is mostly spruce, in addition to columns, beams, sparre buckets rafters, etc. used in building supporting frames, while also used in door railings, window frames and interior floors (Fig. 11).

Fig.11 Wood Use in Labrang Monastery

In addition, the building materials of Labrang Monastery include bricks, which only cover a small area. Only the summer residential house in Jiamuyang Living Buddha Palace is built with clear water bricks, and the decorative patterns on the bricks are exquisitely carved.

3. Analysis of the Physical Environment of Labrang Monastery

3.1 Architectural acoustic environment

Labrang Temple is located in the west of county town, where far from the downtown area. The temple is surrounded by mountains and rivers on three sides, so it is relatively independent and low external noise harrasment[10]. The materials and construction make the stone-soil wall in the monastery very thick that the walls are usually more than 1m thick. In addition, there are few small windows on the walls, usually there is little noise in the room, which provides a good sound environment for monks to practice and study.

The average noise pressure level of sutra hall in the monastery is L=24.8dB (A) by measuring the Kalachakra academy and Hevajra academy. When 25 monks recite sutras indoor, the equivalent continuous sound pressure level of Kalachakra academy is Leq=68.3 dB(A), which is within the appropriate sound pressure level for the talking sound environment.

3.2 Building Optics Environment

The control and application of light are very important in religious architectures. Unlike the general indoor lighting standards, Labrang Temple, as a religious building, its lighting environment construction requirements not only meet the site function but also meet the spiritual needs. Taking the Great Sutra Chanting Hall of Labrang Monastery as an example, the space center of the Sutra Hall is partly connected with the second floor, and the high side skylights set on the second floor for daylighting. The overall illumination of the building is very low. The skylight mainly provides the key illumination for the northern rostrum and the Buddhist niche, so as to visually strengthen and reflect the central position of the sacred space in the interior. In addition, the material and construction of the skylight are worth mentioning in the construction of indoor light environment. Flat skylights are set up on the north side of the roof of Kalachakra academy's auditorium. The skylights are fixed on the roof with angle steel brackets. Not all sunken skylights on the roof are such daylighting skylights. The sunken skylights on the south sides of Kalachakra academy's roofs are directly open, that is, daylighting and ventilation and heat dissipation. There are also many high-side skylights, with a thin layer of light-colored paint on ordinary glass, which produces uniform diffusion and penetration. The radiation effect effectively avoids the glare problem caused by direct sunlight around noon time.

The interior overall lighting environment of Labrang Monastery's Sutra Halls is of low brightness. It only lights and illuminates the Buddha statues and niches. This practice not only creates a mysterious religious atmosphere, but also plays a symbolic role of darkness with Buddha's guidance, and achieves a high degree of unity of content and form.

3.3 Building thermal environment

The natural environment of Labrang Monastery is dry-hot climate, with strong solar radiation, large temperature difference between day and night, and few rainfall. Academic buildings and Buddhist monastery buildings are two main types of buildings in Labrang Monastery, which are public buildings in terms of use. Their requirements for building thermal insulation are not high, but their materials and construction methods do reflect the characteristics of energy saving and comfort.

Most of the materials used are ecologically recyclable, such as natural stones, raw soil, timber, margin grass, etc. The roof of stone-soil mixed construction wall and civil mixed construction with thickness more than 1m ensures good thermal performance of the building, making it warm in winter and cool in summer. Spring, summer and autumn are hot seasons in Gannan area. As a good heat storage body, the thick walls absorb a large amount of solar radiation heat during the day. Because of the delayed effect, it does not radiate until night, which ensures that the indoor environment is in a cool state during the day when it is used in high frequency. The thermal comfort effect of winter buildings is not as obvious as that of summer buildings, because the main hall buildings need to open doors in most cases, and the sealing of wood windows is poor, some skylights do not contain glass, so there is not much difference between indoor and outdoor's temperature. In winter, the indoor thermal environment of the Sutra Hall and Buddhist Hall is stable, in a state of no wind or fresh air, which is conducive to keep awake and quick thinking when monks concentrate on reciting sutras.

Labrang Monastery building does not need air conditioning in summer or heating in winter (mainly refers to academic buildings and Buddhist halls). The above thermal environment effect can be obtained only through materials and construction. The cost is low, and the ecological environment protection is high-performance[11]. This has certain enlightenment for the protection and inheritance of Tibetan Buddhist buildings and even for the design of public buildings.

4. Conclusion

The building materials and construction of Labrang Monastery have great influence on the acoustics, optics and thermal environment of the building. From the perspective of architectural technology, this paper interprets the architecture of Labrang Monastery, which not only provides more references for the protection and renovation work, but also triggers some reflections on the design of modern religious architectures.

1)Location:

On the view of acoustic environment control, we should avoid densely populated areas and choose quiet places with good natural environment;

2)Space layout:

From the perspective of optics environment, religious spaces should not only conform to the functions of religious activities, but also to meet the spiritual needs, and to strengthen the grasp and utilization of natural lighting;

3)Building energy efficiency:

We should make the best use of adjusting and designing the thermal environment of the interior space via physical means so as to make the buildings with "free breath" and ecologically sustainable.

Acknowledgements

This paper is supported by the National Natural Science Foundation of China(NO. 51568038), the National Natural Science Foundation of China,(NO. 51608421) and the PhD Foundation of Weifang University(NO. 2018BS13)

References

[1] Xinya Xu. Traditional Tibetan Religious Architecture of Labuleng-Monastery, J. World Architecture. 8 (2006)110-113.

[2] Yunying Ren, Qi Gao. The landscape pattern analysis of Labuleng Temple, J. Architecture and Culture. 76(01):50-51.

[3] Jiayan Han. Space mode analysis of religious architecture in Inida, J. Journal of Xi'an University of Architecture and Technology. 12 (2002)379-382.

[4] Lin Cai. Henan Qinwang of Qinghai and Labrang monastery, J. Journal of Qinghai normal university (philosophy and social sciences), 39(2017)83-86.

[5] Blobzang Tshering. A textual research on the relationship between the 9th Panchen and Labrang Lamasery, J. Tibetan Studies, 2(2017)24-30.

[6] Qi Gao, Yunying Ren. The study of space model about the building of sutra chanting hall of Tibetan Buddhism temple in Gannan area, J. Journal of Xi'an University of Architecture & Technology(Natural Science Edition). 50(2018) 78-84

[7] Meji Zhuo. A brief introduction to the Labrang event, J. Journal of Sichuan Minzu College. 26(2017)41-45.

[8] Zhihe Guo. Urbanization study on the type of business around temples in the Tibetan area, J. Journal of Tibet University. 30(2015)103-113.

[9] Zhiwei Zou, Yongjian Hou. Monk's system of labrang temple and ecological environment in the south Gansu Tibetan area during the period of Republic of China, J. Northwest Population. 33(2012)93-97

[10] Dpav-ris-don-grub. The relationship of dharma between four Gulug temples in Tibet and Labolung temple in Gansu, J. Journal of Tibet national institute (philosophy and social science). 31(2010)30-38.

[11] Ping Zhang, Xinya Xu, Hua Chen. Brief analysis of building special layout in Labuleng temple, J. Shanxi Architecture. 34(2008)52-53.