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チベット高原におけるサンルーム付き住宅の空間形態の分析

Architectural Form Analysis of the Sunroom Residences on Tibetan Plateau

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As a new residential component, the sunroom on Tibetan Plateau has led to contradictions between function and spatial forms. There is therefore a need to understand the sunroom houses from the aspect of local residences' residential habits and common awareness. A detailed description of the mapped houses is presented, the functional layout and spatial form of sunroom houses are summarized, and the spatial order of residences is analyzed. Results shows that the sunroom serves as a primary living space and is well integrated into the original inner logic of the residence, but there are still some unreasonable aspects. Results not only provide information for future thermal environment monitoring and simulation of sunroom but also provides practical suggestions for the improvement of it from the aspect of architectural culture.

Keywords: Architectural Form, Tibetan Plateau, Sunroom, Vernacular Building
建築空間形態，チベット高原，サンルーム，ヴァナキュラー建築

1. Introduction

Over the past few decades, sunrooms have proved to be effective to improve comfort and reduce heating energy consumption. It is a recommended passive heating technology in all climatic regions of China and has a high penetration rate in rural areas.

On Tibetan plateau, the sunroom is a new residential component that emerged after the popularization of glass as a building material. It has created a certain fragmentation with the original residential system and has caused a change in the original spatial order of the house. This has led to some contradictions between contemporary functional requirements and traditional spatial forms. There is therefore a need to understand the sunroom houses on the Tibetan plateau from the aspect of the local people's living habits as well as their common awareness and ethnic perceptions.

In previous researches, Tibetan vernacular building has been studied from the perspective of structure, decoration, material and so on. However, very few have paid attention to sunroom the new component.

Therefore, this paper delved into the spatial morphology of sunrooms and the distinctive notion of dwelling that underlies them, putting forth approaches to enhance the form of sunrooms while respecting and safeguarding residential cultural contexts. First, a detailed description of the mapped dwellings is presented; then, the functional layout and spatial form of sunroom residences are summarized; finally, the role of sunroom in the spatial order of residences is analyzed.

The purpose of this paper is: 1) To organize the necessary information for future thermal environment monitoring and simulation, so as to optimizing the design of sunrooms as heat collectors to meet the residents' thermal needs better; 2) To understand the role of the sunroom in the overall spatial order of the rural residence in the Tibetan Plateau as a new unit, and to evaluate the integration and change of the sunroom into the original housing system, thus to understand which features of the sunroom meet and which ones go against the physical and spiritual needs of the local people, and providing suggestions for the redesign of the

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sunroom. The results of the study contribute to an in-depth understanding of the sunroom from the perspective of architectural culture. In this way, the advantages and disadvantages of the sunroom can be identified as an addition to the house in dealing with the contradiction between modern functional needs and traditional architectural forms, and provide practical suggestions for solving the contradiction between "new needs" and "old houses".

2. Research area and object

2.1 Tibetan plateau

The Tibetan Plateau is located on the southwestern border of China, the birthplace of many rivers in East and Southeast Asia, an important area for environmental security. People of many ethnic groups such as Han, Tibetan and Yi have lived here for a long time. The Qinghai-Tibet Plateau is a severe cold and cold region, with cold winters and long heating periods. Taking Lhasa as an example, the heating period is 130 days. At the same time, the Qinghai-Tibet Plateau is rich in solar energy, the annual sunshine duration reaches 2900-3400 hours, and the total annual solar radiation can reach 7000-8400 MJ/m2. These climate characteristics make it the most suitable area for sunspaces.

2.2 The history of using glass and building sunroom on Tibetan plateau

Before the 1950s, most residences in Tibet were noble estates, while many serfs had no houses to live in. After the peaceful liberation of Tibet in the 1950s, people began to build their own houses. Due to extremely low productivity, window panels were made of materials such as wood boards, paper, animal hides, while glass gradually became applied in the houses of wealthy families. There are not many houses built during this period that have survived to this day.

From the 1990s to the early 21st century, with increased government investment in Tibet, the region experienced sustained economic growth and a peak period of residential construction. At this time, glass was widely used in residential construction. Many of the houses built during this period are still in use today.

Since the beginning of 21st century, with the implementation of the Western Development Strategy, Tibet's economy has seen rapid development, and a large number of sunrooms enclosed by glass have been built. These sunrooms have a large area and are importance living space. They generally have furnishings such as curtains, Tibetan sofas and coffee tables, Tibetan sideboards, fireplaces, TVs and decorations such as flowers, wall paintings. In these sunrooms, residents relax, entertain, make tea, sleep, eat, work and study.

3. Literature review and research gaps

The unique and rich Tibetan culture has first attracted a group of Western scholars, since the mid-20th century, books which include various aspects of Tibetan civilization such as architecture, history, religion and art were published.[1),2)] Since the late 20th century, many Chinese scholars have introduced the history, types, structures, decorations, materials, and other aspects of Tibetan architecture through surveying and mapping, gradually making people aware of the uniqueness of Tibetan architecture.[3),4),5),6)] Since the 21st century, Western scholars who are committed to the research of Tibetan architectural culture are still not few,[7),8)] and Chinese scholars' research on Tibetan architecture has become more abundant and more detailed. For example, Gongsang Nima, etc.[9),10),11),12)] conducted in-depth analysis of the color characteristics of Tibetan architecture and its inherent influencing factors; Li Peng, etc.[13),14),15),16),17)] conducted experiments or simulations on the structural system and mechanical properties of Tibetan architecture, and provided references for repair and seismic resistance of Tibetan architecture; Xia Tian, etc.[18),19)] introduced the material of Tibetan architecture and proposed regional adaptability strategies for materials; and Zhang Yingzi, etc.[20),21),22),23)] studied the relationship between architecture and regional climate from the perspective of climate adaptation.

The above research has analyzed Tibetan architecture in great detail. However, the sunroom is a residential unit that has only "barbarically grown" after 2000, and it is an additional construction after occupancy, not a part of formal construction. Therefore, there are few studies that conduct microscopic analysis on this "informal" residential unit. However, the sunroom still reflects the real housing needs of residents and cannot be ignored and needs scientific guidance as well.

4. Field survey situation

Lhasa is a representative city of the Tibetan Plateau. On the one hand, it has the typical plateau climate characteristics of cold winter and cool summer and strong solar radiation.

On the other hand, it is the political, economic, religious and cultural center of the whole Tibetan Plateau. Therefore, Lhasa rural residence is chosen as the object of the study.

A main house, and several attached houses and courtyard walls enclosing the courtyard, is the most common form of residence in rural Lhasa. From 2016 to 2023, the research team conducted multiple investigations on this kind of rural residences in Cai Village (91°22' E, 29°64' N) and Najinbeilu Community (91°15' E, 29°66' N) of Chengguan District, Bairong Village (91°40' E, 29°81' N) and Tiechong Village (91°42' E, 29°79' N) of Linzhou County in Lhasa. The investigated areas are shown in Fig. 1. A total of 41 residences were visited, in which 15 typical ones were mapped in detail. The situation of whether they have sunrooms, whether they are mapped or presented as an example in later texts are shown in Table 1.

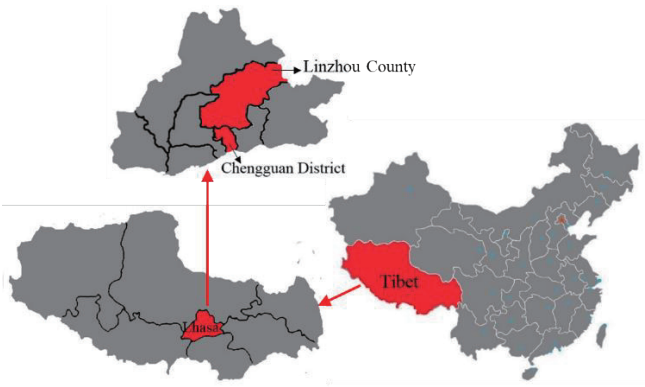


Fig. 1 Investigated areas

Table 1 Surveyed residences

	With sunroom	Without sunroom	Total
Visited and photographed	9	32	41
Mapped	4	11	15
Presented below as examples	2	1	3

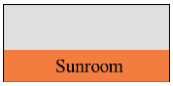
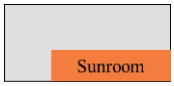
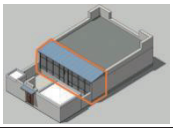
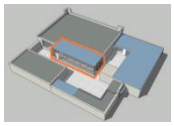
5. Classification and examples of sunroom residences

5.1 Classification of sunroom residences

Based on the 9 investigated sunroom houses, the sunroom houses can be classified as follows.

According to the position of sunroom on the façade, most of the sunrooms are on the first floor of the residence, with a few on the second floor. According to the position of sunroom on the plane, sunroom can be added to the original rectangular plane, L-shaped plane, or U-shaped plane, as shown in Table 2. Sunrooms are generally rectangular, but there is also a small number of sunrooms with irregular shapes such as concave and convex.

Table 2 Classification of houses with sunroom

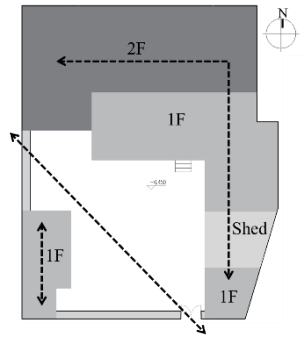
	Rectangular-shaped plane	L-shaped plane	U-shaped plane
floor plan			
mode 1			

5.2 Examples of residences

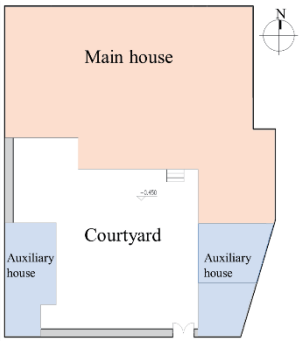
In order to explore the spatial relationship of Tibetan residence, 3 houses including 2 with sunroom and 1 without sunroom were selected from the 15 mapped houses, and were presented in this section.

1) Residence No. 1 (with sunroom)

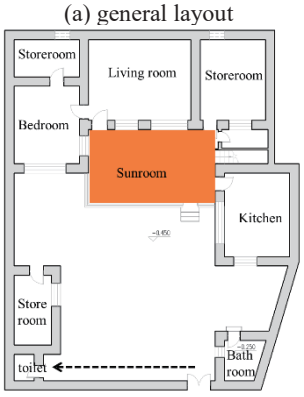
As Fig. 2 and Fig. 3 show, residence No. 1 faces south, the main house has 2 floors, before the addition of the sunroom, the first floor was asymmetrical U-shaped, the second floor was L-shaped, the addition of the sunroom made the first floor grow into a stepped shape. The southeast and southwest corners of the courtyard are bathrooms, toilets and utility rooms. From the general plan, the courtyard is formed by a large L-shaped volume on the northeast side and a small rectangular volume on the southwest side, with a northwest-southeast oblique-through shape.

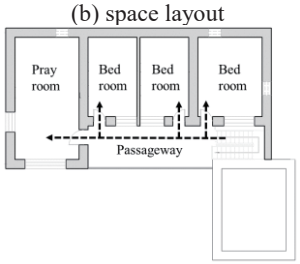


(a) general layout



(b) space layout





(c) traffic layout

Fig. 2 Layout of residence No. 1

2) Residence No. 2 (with sunroom)

As Fig. 4 and Fig. 5 show, residence No. 2 faces south, the main house has 2 floors, before the addition of the sunroom, the first floor was symmetrical U-shaped, the second floor was L-shaped, the addition of the sunroom made the first floor grow into a convex shape. The main gate is located on the east side, and there is a toilet in the southwest corner of the compound. From the general plan, the courtyard is formed by the main house on the north side, with an east-west cross-through shape.

The spatial sequence of Residence No. 2 is: outside - courtyard - sunroom - other rooms on the first floor of the main house. Since the stairs that connect the first and second floors are outdoors, the sunroom is only a hub for horizontal traffic.

3) Residence No. 3 (without sunroom)

As Fig. 6 and Fig. 7 show, residence No. 3 has no sunroom. Residence No. 3 faces south and has a rectangular-shaped main house of 1 story. 2 courtyard gates open to the south and west, with the south gate being the main gate used. The east side of the compound has a kitchen, a bedroom, and a store room. A storage shed is located along the south side of the compound. From the general plan, the courtyard is formed by the main house on the north side and the auxiliary house on the east side, with a northwest-southeast oblique-through shape.

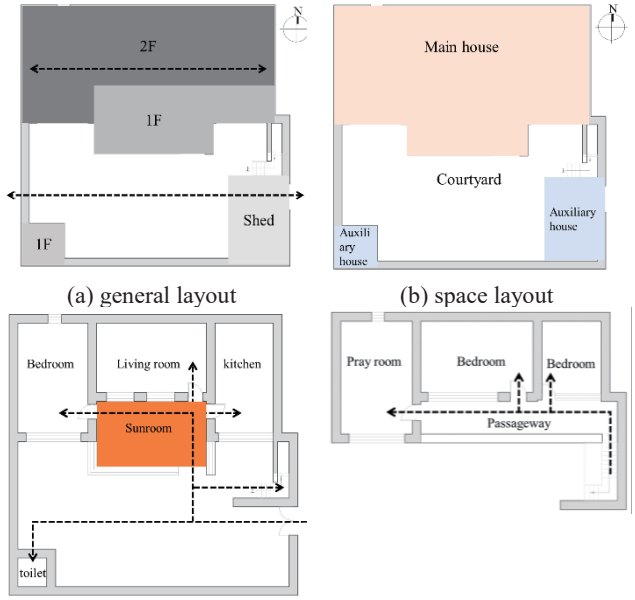
The sequence of spaces in Residence No. 3 is: outside - courtyard - living room - other rooms in the main house. The living room is the traffic hub.

6. Basic information of house with sunroom

According to the collected information from these 41 residences, the common characteristic of the rural residence and sunroom can be summarized in this section.

The spatial form and functional layout of the sunroom residences are shown in Fig. 8. The sunroom residence contains 3 main parts: the main house (including the sunroom), the auxiliary houses and the courtyard. The interior of the main house includes the main living space such as the pray room, living room, bedroom, kitchen and sunroom. The auxiliary houses have toilet and production spaces such as livestock sheds and storage rooms for agricultural tools. The courtyard is enclosed by the main house and the auxiliary houses. It is the transportation space connecting the main house and all the auxiliary houses, and the place for some production and living tools which are used in the open air.

Fig. 3 Photos of residence No. 1



(c) traffic layout

Fig. 4 Layout of residence No. 2

Fig. 5 Photos of residence No. 2

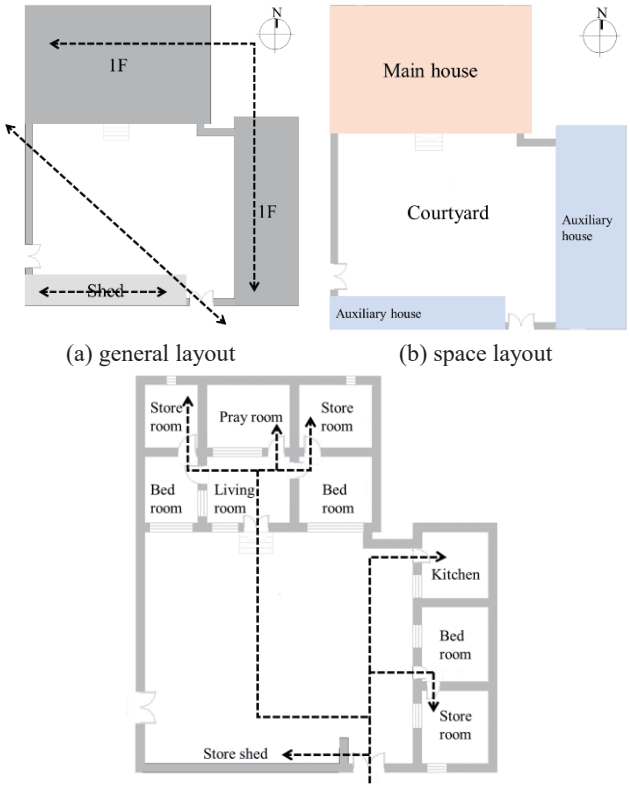
6.1 Main house

The main house is usually 1 or 2 stories, facing south. The main house has the function of daily living of the residents and the worshipping of the gods. The photos of each part of the main house are shown in Fig. 9.

In traditional Lhasa rural residences, the functions of leisure, meeting, cooking, tea making and even sleeping are not separated, but is done by the whole family in one main room: The waste heat from cooking and tea making can heat the room, and the wide Tibetan sofa can be used as a bed at night. With the abundance of resources, the Lhasa rural residences gradually divided into multiple rooms such as bedrooms, kitchens and living rooms. However, the inhabitants still love the way of living with most of the functions in one big room instead of being separated. As a result, the current Lhasa rural residences have many rooms, but the functional differentiation is not very obvious, as shown in Fig. 10.

The function of praying is clearly and completely separated and housed in the pray room. The pray room is located on the highest floor of the main house, and the residents create a quiet and sacred environment in the pray room through luxurious decorations, burning incense, playing chanting, and semi-translucent curtains. The function of cooking is housed in the kitchen. The bedroom assumes the function of sleeping, but the residents sometimes sleep in the living room or the sunroom. The living room and sunroom have the same functions: eating, making ghee tea, recreation, meeting guests, sleeping, etc. It can be said that the sunroom is the second living room used by the residents at the time when its internal environment is suitable.

The sunroom is an addition to the front porch. The front porch is a semi-open space in front of the main house. The front porch is usually enclosed by high walls on the east, west and north sides, and a short wall of about half a meter on the south side. There is a height difference of about three steps between the front porch and the courtyard. The short wall and the height difference distinguish the front porch from the courtyard and make it part of the main house. The wide pickets are able to provide half shade to the front porch. Lhasa has plenty of solar energy in winter, and the main wind direction is east and west. The front porch provides both sunlight and protection from the cold wind, making it an important winter living place. After the popularity of glass, its greenhouse effect has also been spontaneously used by local

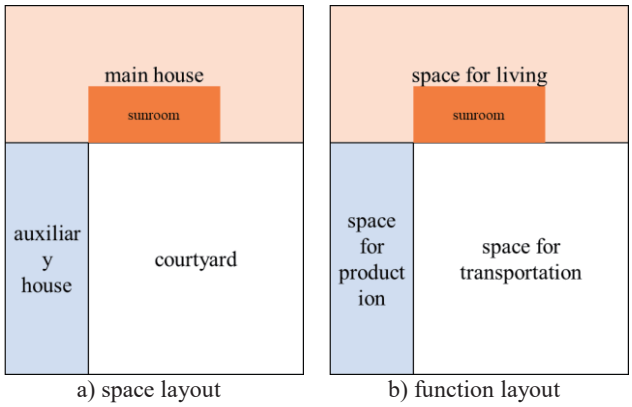


(a) general layout (b) space layout

(c) traffic layout

Fig. 6 Layout of residence No. 3

Fig. 7 Photos of residence No. 3



a) space layout b) function layout

Fig. 8 Space and function layout of house with sunroom

residents. People installed large windows on the low walls of the front porch, and sealed the roof with color steel tiles, making it from the front porch into a sunroom. The front porch and sunroom are the horizontal traffic core inside the main house, connecting all the rooms on the first floor; sometimes they are also the vertical traffic core, connecting the first and second floors of the main house.

6.2 Auxiliary house

The auxiliary houses include toilet, livestock shed, storage and garage. Photos of each part of the auxiliary houses are shown in Fig. 11.

Toilets are physically and mentally unclean to the local people, so they are placed in the farthest corner from the main house even if it is inconvenient to use them. At present, although the toilets are much cleaner than before, and bathing function is added in addition to the toilet function, the residents still used to place them in a corner of the courtyard. Agricultural and pastoral tools, wood, fuel and other miscellaneous items are usually stacked along the courtyard wall and covered with some waterproof material. With very little rainfall in the area, open-air storage is basically sufficient, but some families also build storage rooms or sheds. Transportation is also usually stored in the open air near the main house, but some families also build garages or carports.

6.3 Courtyard

The courtyard is an enclosed one surrounded by houses or heavy walls of 2-3 meters high, with only one main gate. It is highly private and defensive. Photos of various parts of the courtyard are shown in Fig. 12.

The courtyard is the transportation core of the entire house. The courtyard connects the exterior of the house, the main house and all the auxiliary houses. The traffic relationship of the whole house is shown in Fig. 13.

In addition to being the core of transportation, the courtyard also performs a number of domestic and productive functions, such as washing and drying clothes, using solar cookers to boil water, keeping pets, planting flowers and grass, stacking miscellaneous items, parking transportation in the open, etc.

7. The role of sunroom in the residence's spatial order

The residence is not only a combination of building materials and furniture, but the formation of the residence conforms to a certain inner order in terms of space, function

a) pray room b) living room c) kitchen d) front porch e) sunroom f) bedroom

Fig. 9 Photos of main house

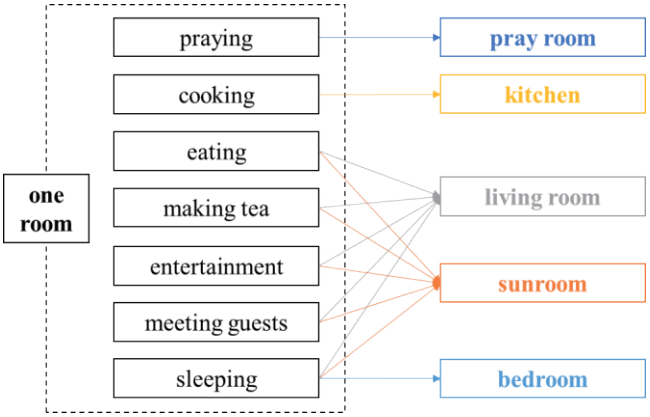


Fig. 10 Distribution of main house's function

a) toilet b) livestock shed c) garage d) storage shed

Fig. 11 Photos of auxiliary house

and psychology, and is the material expression of the social nature of the residents. As a new unit, the sunroom cannot exist apart from the inner order of the whole residence. This subsection takes one of the residences as an example to analyze the north-south order and up-down order of sunroom residence and the role of sunroom in these inner orders.

7.1 North-south order

1) North-south order at the spatial level: closed space - open space

Rural houses in Lhasa are generally oriented from north to south, with house, sunroom, courtyard, entrance and exterior in that order. The house is an enclosed space enclosed by four walls and a roof; the front porch is a semi-open space enclosed by three walls, a low wall and half of the eaves; the courtyard is an open space enclosed by walls and houses and is without a roof. The comparison of the degree of enclosure of the house, front porch and courtyard is shown in Fig. 14 (a). Therefore, there is an order of "closed space – semi open space - open space" from north to south at the spatial level.

After the front porch is converted into a sunroom, the existence of windows and curtains allows residents to freely adjust the degree of connection between the sunroom and the courtyard, including the view and the physical environment of wind, light and heat. The existence of the sunroom turns the semi-open space into a closed space, and there is an order of "closed space - open space" from north to south, as shown in Fig. 14 (b).

2) North-south order at the functional level: secondary living space - primary living space - production space

The north side of the main house in rural Lhasa has poor lighting and low temperature, which is the secondary living space such as storage room and stairway, while the south side has better light and heat environment, which is the main living space such as living room, bedroom and kitchen.

The front porch is also an important living space, usually with potted plants on the low wall, clothes drying under the eaves, and sofas placed against the wall, where people drink tea, do housework and relax in good weather. The courtyard also tends to have living functions close to the main house and production functions close to the gate, as shown in Fig. 15 (a).

After the front porch is converted into a sunroom, there is no wind and no rain and the temperature is higher in winter, the residents placed TVs, tea stoves, potted plants, fine Tibetan sofas and coffee tables in the sunroom and spent even more time in the sunroom. A comparison of the furnishings

a) door b) clothes being dried

e) solar cooker f) pets and plants

Fig. 12 Photos of courtyard

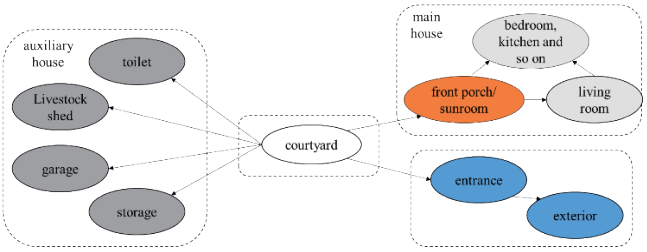
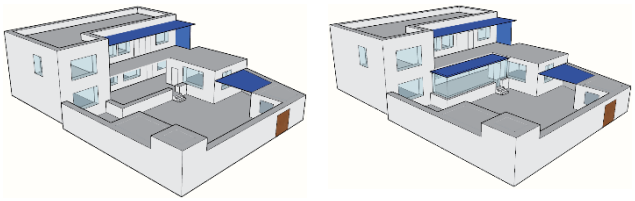


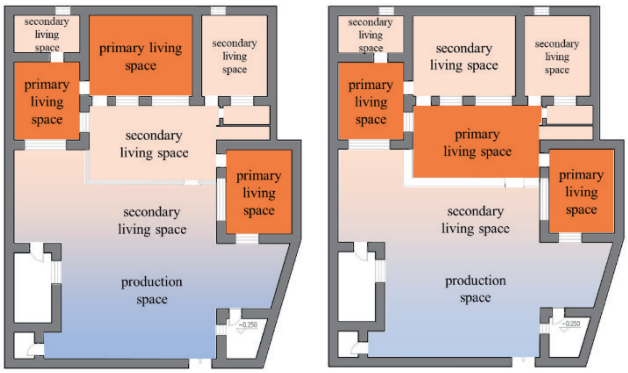
Fig. 13 Traffic organization of the entire house



(a) without sunroom: closed space - semi open space – open space

(b) with sunroom: closed space – open space

Fig. 14 North-south order at the spatial level



(a) without sunroom: living room is more important than sunroom

(b) with sunroom: sunroom is more important than living room

Fig. 15 North-south order at the functional level

in the sunroom and the front porch is shown in Fig. 16. The sunroom is used more frequently, while the living room becomes a north-facing room and is used less frequently. The existence of the sunroom reverses the primary and secondary relationship between the front porch and the living room, as shown in Fig. 15 (b).

3) North-south order at the psychological level: tidy – messy

The spiritual core is the original point of tidiness. The further away from the origin, the more disorganized it is, as shown in Fig. 17. The pray room has the highest level of cleanliness, followed by the living room, kitchen, bedroom and other rooms of the main house, followed by the front porch or sunroom, and the most disorganized places are the secondary houses and courtyards.

The cleanliness of the sunroom is higher than that of the original front porch, but still lower than that of the living room. This is because after the construction of the sunroom, although the sunroom and the living room have similar functions, the function of the sunroom is more focused on "daily use by the family", while the function of the living room is more focused on "showing to guests".

7.2 Up-down order

1) Up-down order at the spatial level: rooftop – 2^{ed} floor – 1st floor – courtyard

As shown in Fig. 18, the courtyard is the lowest point of the whole house. There are several steps between the first floor (including the front porch) and the courtyard. This is partly because the house is built on the mountain, but also reflects the difference of the main house and the courtyard in the functional and psychological status.

If there are two floors, then the area of the second floor is less than or equal to the area of the first floor, and there will not be a situation where the first floor is overhead. This is in line with the structural characteristics of Lhasa's rural houses, where the walls and columns are jointly load-bearing, as well as its solid and heavy aesthetic characteristics. The first and second floors are generally connected by an open-air staircase, while some residences place the staircase on the north side of the main house. The roof is a platform, and since there is little rain in the area, it is a flat roof for residents to climb up and dry their things. The roof is enclosed by a parapet of about 0.5m. There are usually no stairs between the second floor and the roof, which are connected only by simple steel or wooden ladders.

(a) front porch: simply-furnished

(b) sunroom: well-furnished

Fig. 16 Furnishing comparison between front porch and sunroom

(a) pray room: the tidiest space

(b) living room: the second tidy space

(c) sunroom: a little bit messier than living room

(d) storage in the yard: the messiest space

Fig. 17 North-south order at the psychological level

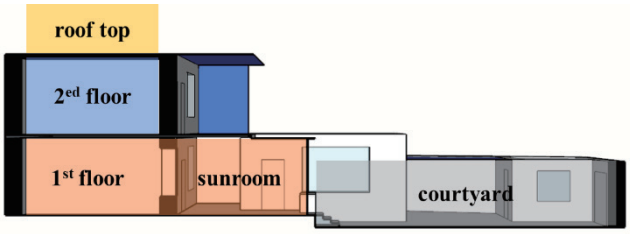


Fig. 18 Up-down order at the spatial level

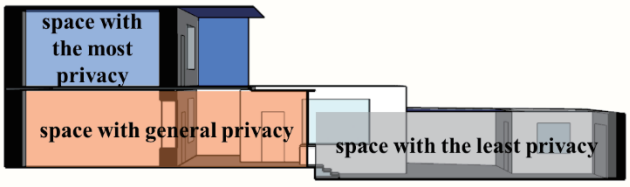


Fig. 19 Up-down order at the functional level

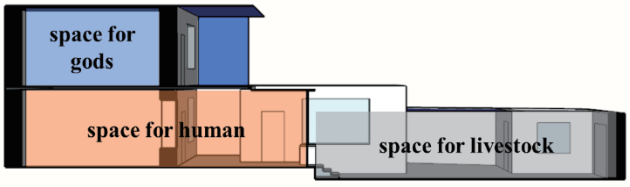


Fig. 20 Up-down order at the psychological level

The sunroom is part of the first floor of the main house and has the same floor height as the other first floor rooms. However, roofs built with color steel tiles generally slope downward, and the height of the sunroom is lower than other rooms

2) Up-down order at the functional level: space with the most privacy – space with general privacy – space with the least privacy

As shown in Fig. 19, the courtyard has the least privacy, and delivery person and others can enter. The first floor is usually arranged with living room, kitchen and other public places, which are shared by family members and can also be used for guests. The second floor is generally arranged with bedrooms and pray room, which are places of greatest privacy. The distribution of private and public space in Lhasa rural residences is the same as in other regions.

The sunroom, functionally, is also a space shared by the family and can entertain guests, so it is generally located on the first floor and less often on the second floor.

3) Up-down order at the psychological level: space for gods – space for human – space for livestock

As shown in Fig. 20, god's space - the pray room must be placed in the highest place, in two-story houses, it is generally located on one side of the second floor, and it has the quietest environment. Human's space - the bedroom is on the second floor or the first floor, and the living room, kitchen and other spaces are on the first floor of the main house. Livestock's space - livestock sheds are generally placed in the courtyard. This arrangement is the external expression of the order of "God - human - livestock" in Tibetan Buddhism.

8. Conclusion

This research summarizes the common characteristics of sunroom residences through the survey of several residences in Lhasa, and provides an information basis for the following thermal environment monitoring and simulation of sunroom residences. Facing the contradiction between new functional demands and old residential spaces, residents spontaneously use sunrooms to solve it. By analyzing the inner logic of the residential space of the sunroom, this research understands how the sunroom fits or violates the material and spiritual needs of the residents, and thus provides practical suggestions for the improvement of the sunroom. The main conclusions of this chapter are as follows:

1) Tibetan sunroom residences typically consist of 3 main parts: the main house (including the sunroom), auxiliary houses, and the courtyard. The main house serves as the primary living space. The sunroom, an extension of the front porch, provides a winter living space with sunlight and protection from cold winds. This information provides the basis for the selection of optical and thermal environment monitoring subjects. It also provides guidance for simulation. The main house is the object of the simulation, and auxiliary houses and courtyard can be considered as shading of the main house.

2) In general, the sunroom is well integrated into the original inner logic of the residence at all levels of space, function and psychology. However, there are still some unreasonable aspects of the current sunroom:

a) The closed space replaces the semi-open space of the front porch, which reduces the level of openness of the entire residence and reduces the residents' opportunity of a semi-outdoor life. Therefore, it is advisable to to create a semi-open space within the courtyard by raising the foundation and adding movable sunshades, ensuring a diverse living space for the residents.

b) It makes the center of residents' life shift southward, thus forming a complete secondary living space on the north side. The north and south side of the residence has a clear separation of primary and secondary, which improves the thermal comfort of residents. While serving as an important living space, the sunroom remains the front porch's "main house traffic core" function. Therefore, it is necessary to redesign the interior doors and windows to ensure that the traffic and the use of furniture do not conflict in the sunroom.

c) The roof of the sunroom is mostly made of color-coated steel, the material is temporary, and the height of the addition is low, which does not meet the residents' expectation that the sunroom is tidy and a major living space. Therefore, the roof of the sunroom should be built to the same height as the other rooms with durable building materials.

In future research, an optical and thermal environment will be conducted in a typical sunroom residence to analyze the light and heat transfer characteristics of existing sunroom; and the sunroom will be optimized by simulation based on resident's thermal needs.

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