

# Research on the Performance and Usage Conditions of Exterior Windows of Watchtowers and Residential Buildings in the Western Sichuan Plateau

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## Abstract

In the context of the country's advocacy of "low carbon energy saving", this article focuses on the research on the economical and energy-saving selection of exterior windows of watchtower buildings in the western Sichuan Plateau area, and conducts field research. On the one hand, in the literature part, it investigates domestic and foreign opinions on architectural The study on the energy saving of exterior windows, on the one hand, investigated the economic research on building exterior windows at home and abroad. In the field survey part, it was found that studying the economic selection and design of exterior windows of watchtowers and residential buildings in the western Sichuan Plateau region has both energy saving and benefits for the country and the people. To control the value of economy, in order to explore how the exterior windows of watchtowers and residential buildings affect the energy consumption and economy of residential buildings in the Western Sichuan Plateau, the goal of economical and energy-saving selection of exterior windows of watchtowers and residential buildings in the Western Sichuan Plateau was formulated to provide information for deepening the subsequent economic and energy-saving selection.

## Keywords

Full Life Cycle, Exterior Windows of Watchtowers and Residential Buildings, Usage Status and Performance.

## 1. Survey on the Current Situation of Residential and Building Exterior Windows in the Western Sichuan Plateau

### 1.1. Survey and site selection of residential buildings on the Western Sichuan Plateau

After sorting out the previous literature, a preliminary survey was carried out on the exterior windows of the watchtowers and residential buildings in the Western Sichuan Plateau to understand the climate environment in which the exterior windows of the watchtowers and residential buildings in the western Sichuan Plateau were located, and the use of the exterior windows of the watchtowers and residential buildings throughout the life cycle. This was recorded through retained image data.[1]Information related to the exterior windows of watchtowers and residential buildings laid the foundation for later research on the exterior windows of watchtowers and residential buildings in the Western Sichuan Plateau.[2] Aba Prefecture, a three-state area in the Western Sichuan Plateau, was selected to conduct a survey on the current status of exterior windows of watchtowers and residential buildings in the Western Sichuan Plateau.[3]

#### 1.1.1. Geographical location

This article explores the Aba Tibetan and Qiang Autonomous Prefecture in the Western Sichuan Plateau. The Aba Tibetan and Qiang Autonomous Prefecture is located on the southeastern edge

of the Qinghai-Tibet Plateau and in the northwest of Sichuan Province, between  $100^{\circ}0' \sim 104^{\circ}7'$  east longitude and  $30^{\circ}5' \sim 34^{\circ}9'$  north latitude. The most representative capital of Aba Tibetan and Qiang Autonomous Prefecture: Markang was selected for in-depth investigation and research.[4]

Tibetans are one of the 56 ethnic groups in China and are the indigenous people of the Qinghai-Tibet Plateau. In China, it is mainly distributed in Tibet Autonomous Region, Qinghai Province and western Sichuan Province, Diqing, Yunnan, Gannan, Gansu and other regions. The history of Tibet is an integral part of Chinese history. [5]The Tibetan people have created a splendid national culture and left an extremely rich cultural heritage in literature, music, dance, painting, sculpture, architectural art, etc.

The most representative Tibetan dwelling is the Diao Fang, which is a common form of living in the Qinghai-Tibet Plateau in southwest China and parts of Inner Mongolia. [6]Judging from the records in "Book of the Later Han", it existed before the sixth year of Yuanding in the Han Dynasty (111 AD). This is a house made of rubble or earth, with a height of three to four stories. Because its appearance resembles a fort, it is called a blockhouse.[7] The name of the blockhouse can be traced back to at least the Qianlong period of the Qing Dynasty (1736 AD).



**Figure 1:** The geographical location of the western Sichuan Plateau

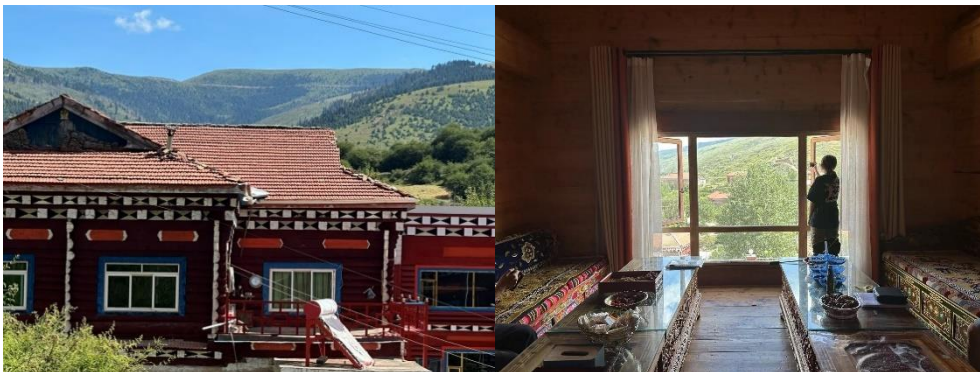
### 1.1.2. Climate characteristics

The climate characteristics of the Western Sichuan Plateau are mainly characterized by plateau climate and mountain climate. The Western Sichuan Plateau is located at a higher altitude and has a cooler climate, with relatively short summers and relatively long winters. The average annual temperature is low, with the average summer temperature around  $15^{\circ}\text{C}$  and the average winter temperature below  $0^{\circ}\text{C}$ . [8] The temperature difference is large, and the temperature difference between morning and evening is obvious. The Western Sichuan Plateau has undulating terrain, criss-crossed mountains, and obvious vertical zoning characteristics in climate [9]. Altitude changes lead to differences in temperature, precipitation, and climate types. Alpine areas have lower temperatures, cold climate, and more annual precipitation [10]; valley areas have moderate temperatures and moderate precipitation; intermountain basins have higher temperatures and less precipitation [11].

### 1.1.3. Building types and basic characteristics

The residential buildings in the Western Sichuan Plateau mainly include traditional architectural types of Tibetan, Qiang, Yi and other ethnic minorities, which have unique characteristics and styles. The research object of this article is the exterior windows of Tibetan watchtowers in the Western Sichuan Plateau[12].

Tibetan houses: Common types of Tibetan houses include Tibetan houses with civil structure and Tibetan houses with stone and wood structure[13]. Most of the watchhouses are made of stone and wood, with thick outer walls and a simple and rough style. The outer walls shrink upward, and if they are built against the mountain, the inner slope is still vertical. Diaofang is usually divided into two floors, and the number of rooms is calculated by columns. The ground floor is the livestock pen and storage room with a low floor height; the second floor is the living floor, with the large room used as the main room, bedroom, and kitchen, and the small room used as the storage room or stairwell. If there is a third floor, it is mostly used as a sutra hall and terrace. Because it looks like a fort, it is called a fort. Generally speaking, a fort is a multi-story building. The bottom floor can be used as a pen for livestock, the second floor can be used as a living room, storage room, etc., and the third floor can be used as a sutra hall. Offer Buddha statues, light butter lamps, etc. In Lhasa and other places, most of the three-story or higher tower houses we can see were built by old Tibetan nobles. There are also houses that only build bungalows.



**Figure 2:** Diaolou residential buildings on the western Sichuan Plateau (self-photo by the author)

## 1.2. Investigation on the performance and usage of exterior windows of buildings

### 1.2.1. Research purpose

By investigating the current situation of the exterior windows of the watchtowers and residential buildings in the Western Sichuan Plateau, we can learn about the types, prices and energy consumption of the existing exterior windows of the watchtowers and residential buildings in the Western Sichuan Plateau. On this basis, we can explore the selection of exterior windows of the buildings. Methods for building energy conservation and emission reduction to improve the energy efficiency of residential buildings and reduce energy consumption and carbon emissions.

### 1.2.2. Research content

In order to study the current status of exterior windows of residential buildings in watchtowers on the Western Sichuan Plateau throughout the life cycle, we started with the exterior windows of residential buildings in watchtowers in Western Sichuan during the entire life cycle, the

current status of building exterior windows and building energy consumption, and the current situation of building exterior windows and economic costs.

(1) Basic information on exterior windows of watchtowers and residential buildings in the Western Sichuan Plateau throughout the life cycle

Field investigation of how the exterior windows of watchtowers and residential buildings in the Western Sichuan Plateau are composed throughout the life cycle. At the same time, when performing simulation calculations, a specific model of the Western Sichuan Plateau is needed, including the building's construction age, building type, and building structure. , building size parameters, the area of the test room, the orientation of the test room and the area of the exterior windows, the types of doors and windows, the integrity of the building structure, the building window opening status at the time of testing data, the electricity consumption in summer and winter, and the use of electrical appliances, while painting Related building envelope sketches

(2) Current status of energy consumption of exterior windows of watchtowers and residential buildings on the Western Sichuan Plateau throughout the life cycle

In order to explore the current situation of energy consumption of exterior windows of watchtower buildings in the Western Sichuan Plateau during the entire life cycle, it is necessary to investigate the location, outdoor weather, climate, gender, age, ethnicity, clothing conditions in real-time weather, and residents' health status of the watchtower houses in the Western Sichuan Plateau. The time in the building, the daily opening and closing time of windows and the reasons for opening windows, the forms of heating or insulation used during hot and cold periods, what you did before the survey, and your feelings about the indoor environment.

(3) Current economic cost status of exterior windows of watchtowers and residential buildings on the Western Sichuan Plateau throughout the life cycle

The economic costs of building exterior windows in the entire life cycle that need to be investigated include: the overall initial purchase cost of exterior windows and associated exterior walls, transportation costs of building exterior windows, installation costs of building exterior windows, (electricity charges) building usage The costs incurred due to heating and lighting energy consumption during the process are determined based on the overall energy consumption and energy prices during the building operation stage. The income from recycling of exterior windows during the building demolition stage, yuan/m<sup>2</sup>, can usually be calculated according to the purchase cost. Calculated as a percentage, the Western Sichuan Plateau is valued at 20% of the purchase. The approximate type of building exterior window glass, the unit price of the building exterior windows, the unit price of transportation and installation, and the inquiries about the cost of residential building decoration in the Western Sichuan Plateau include: construction type, construction Price, building materials used, unit price of materials.

### 1.2.3. Method

(1) Field observation method

Typical cases of watchtowers and residential buildings in the Western Sichuan Plateau were selected for preliminary analysis. Basic information on the exterior windows of the watchtowers and residential buildings in the Western Sichuan Plateau during the entire life cycle can be obtained through on-site observation.

(2) Questionnaire survey method

Based on the current situation of energy consumption and economic cost of exterior windows of watchtower residential buildings in the Western Sichuan Plateau throughout the life cycle, the content of the relevant questionnaire survey was formulated, which is divided into two parts: energy consumption and economics. The specific content is shown in Appendix 1 and 2, which includes building exterior windows. Basic information, energy consumption and



economic status of exterior windows of watchtowers and residential buildings in the Western Sichuan Plateau








### 1.3. Analysis of survey results

There are 100 questionnaires from five areas in the watchtower residential areas of the Western Sichuan Plateau. The types and structures of exterior windows, the economics of exterior windows, and the energy consumption of buildings with different exterior windows will be analyzed and sorted.

#### 1.3.1. Type, structure and physical parameters of exterior windows

According to the analysis of the survey, 100 questionnaires included 32 wooden single-glazed exterior windows, 16 single-glazed plastic steel exterior windows, 16 double-glazed wooden exterior windows, 15 double-glazed aluminum alloy windows, and double-glazed aluminum alloy windows. There are 9 parts of glass broken bridge aluminum exterior windows and 3 parts of low-e glass broken bridge aluminum exterior windows. Generally speaking, the window frame materials are divided into wood, plastic steel, aluminum alloy and broken bridge aluminum. The glass material is divided into single layer glass, Double-layer glass, insulated glass, low-e glass; during the research process, it was found that various window frame materials and glass materials will be matched. Because the research is universal, we only selected the common exterior window types and structures of exterior windows in the building questionnaire. , the other types are shown in Appendix 3.

**Table 1:** Exterior window type and physical parameters

Building exterior window types	Research pictures	Exterior window unit price	thickness	U Heat transfer coefficient	G Solar heat gain coefficient	Tv Transmittance
Single glazed wooden windows(102)		240m <sup>2</sup> /yuan	6mm	5.69	0.823	0.855
Single layer glass plastic steel window(113)		250m <sup>2</sup> /yuan	6mm	5.66	0.774	0.807
Double glazed wooden windows(3419)		300m <sup>2</sup> /yuan	6/16/4mm	2.63	0.44	0.47
Double-glazed aluminum windows(3421)		320m <sup>2</sup> /yuan	6/16/4mm	2.14	0.23	0.2
Double glazed broken bridge aluminum windows(3426)		380m <sup>2</sup> /yuan	6/16/4mm	1.83	0.12	0.08
Low-e glass plastic steel windows(11405)		480m <sup>2</sup> /yuan	6/14/4mm	1.51	0.37	0.47
Low-e glass broken bridge aluminum windows(3437)		520m <sup>2</sup> /yuan	6/16/4mm	1.07	0.09	0.08

#### 1.3.2. Economic efficiency of exterior windows

The economics of the exterior windows of the watchtowers and residential buildings in the Western Sichuan Plateau during the entire life cycle was learned from the survey. The economic

cost of exterior windows in the Western Sichuan Plateau consists of the initial purchase cost of exterior windows, the transportation cost of exterior windows, the installation cost of exterior windows, and the cost of exterior windows. The statistical results are obtained from the costs incurred by energy consumption during use and the recycling costs during the building demolition stage, as shown in Table 2.

**Table 2:** The total cost of building exterior windows throughout the life cycle

Total life cycle cost of building exterior windows/area	Ganzi Prefecture	Aba Prefecture	Liangshan Prefecture
initial acquisition cost	According to the actual research situation, the initial purchase cost of exterior windows is determined based on the actual situation, and the price in each region will fluctuate.		
Building exterior window transportation costs	According to actual research, the unit price of transportation and installation of exterior windows is most likely included in the purchase price of the building.		
Building exterior window installation costs			
Energy price (the unit for this part is the unit price per kilowatt hour of electricity according to the survey)	0.6	0.4	0.35
recycling price	According to actual research, the recycling price accounts for 20-30% of the purchase unit price, but the actual situation is that there is less recycling in the three states.		

After research, the purchase unit prices of exterior window glass and exterior window frame materials for most buildings are shown in Table 3.

**Table 3:** Unit price of various types of exterior windows

Glass type/window frame material	wooden carving(yuan/m <sup>2</sup> )	plastic steel(yuan/m <sup>2</sup> )	Aluminum alloy(yuan/m <sup>2</sup> )	Bridge aluminum(yuan/m <sup>2</sup> )
single glazing	260	280	300	350
double-layered glass	300	320	350	400
Low-e glass	340	360	380	450
heat reflective glass	450	470	490	540
rest of glass	500	520	540	620

**1.3.3. Building energy consumption under different exterior windows**

According to actual research, buildings on the Western Sichuan Plateau are in a relatively cold environment, with almost no need for refrigeration. The main method of heating is to burn fires, which lasts from October, when it starts to be cold, to around April of the following year, 2 months a year. Firepits are used to light fires /3 of the time. The building energy consumption generated in this space far exceeds the electricity consumed by other electrical appliances. Its consumption is 2-3 times of the usual electricity. However, because single-layer glass is commonly used, The differences among the residential buildings surveyed are not very big.

**Table 4:** Monthly energy consumption using each exterior window

Exterior window type	wooden carving(kWh/moon)	plastic steel(kWh /moon)	Aluminum alloy(kWh /moon)	Bridge aluminum(kWh /moon)
single glazing	200	200	200	200
double-layered glass	150	150	150	150
Low-e glass	150	150	150	150
heat reflective glass	150	150	150	150
Rest of energy consumption	300-450	300-450	300-450	300-450

**1.3.4. The daily schedule, lighting and equipment usage patterns of indoor personnel in residential buildings**

The indoor personnel in the watchtower houses in the Western Sichuan Plateau mainly include the male owner, the hostess, parents and children. During the investigation, it was found that the hostess, the elderly and the children basically only go out when there is something temporary, but the male owner usually They all work outside. The specific schedule is shown in Table 5.

**Table 5:** Indoor staff work and rest

Indoor staff's daily routine	Monday - Friday	Saturday and Sunday
woman child old man	at home all day	one day at home
man	the next day8: 00	one day at home

In the residential buildings in the watchtowers on the Western Sichuan Plateau, the lighting equipment is mainly the lighting of halls, bedrooms and Buddhist halls. If the window area is large enough, it will be in a state of natural lighting during the day. The specific situation is shown in Table 6.

**Table 6:** Lighting equipment usage

Lighting equipment type	usage time
Hall incandescent lamp	Always on between 7pm and 11pm from Monday to Sunday
Buddhist temple oil lamp	All day from Monday to Sunday (related to religious customs)
incandescent lamp for bedroom	Monday - Sunday 7am - 9am, 9pm - 11pm
Lighting in other rooms (kitchen, utility room, bathroom)	Only use when necessary (use time 20-30 minutes)

When conducting research on heating equipment, it was found that the stove was kept burning during the cold period from October to April of the following year. From April to October, the stove was used for cooking and heating at the same time. The specific usage time As shown in Table 7.

**Table 7: Heating equipment usage**

Heating equipment type	usage time
fire pond	All day Monday - Sunday (winter) Half day Monday - Sunday (summer)
air conditioner	Use when needed (in the survey, it was found that most of them are only installed in the bedroom area and are not used frequently)

## 2. Conclusion

According to the results of this survey:

(1) The design and use of the exterior windows of the watchtowers and residential buildings in the Western Sichuan Plateau has not been theoretically planned, including the orientation, size, type, etc. of the exterior windows of the building. It's also more casual

(2) According to on-the-spot research, the designers and users of the exterior windows of buildings throughout the life cycle are all residents of the watchtower houses. The residents of the watchtower houses in the Western Sichuan Plateau need to bear the full life cycle economics of the design and selection of the exterior windows of the building. cost, but the choice of exterior window glass still favors simple single-layer glass and double-layer insulating glass. The choice of outer frame is wood, plastic steel, aluminum alloy, broken bridge aluminum, etc., without taking into account the full life cycle. economic and energy consumption impacts

(3) The cost of purchasing exterior windows ranges from 240-600 yuan/m<sup>2</sup> depending on the type of use; in addition, during the use of various exterior windows, the monthly energy consumption level of 100-200kWh and The economic cost is between 100-200 yuan/month. It is also known that residents have high expectations for energy consumption and economic savings.

(4) At the same time, the schedule of people in the building is related to the structure of the family. Generally speaking, the male owner is away from work, while the female owner and her children spend a long time at home doing housework, and spend more time using lighting and heating equipment.

(5) The usage pattern of lighting equipment mainly consists of the common use of oil lamps in halls and Buddhist temples in buildings. However, during the day, the window-to-wall ratio of exterior windows affects daytime lighting. A larger window-to-wall ratio can Reduce lighting from time to time.

(6) Heating equipment is heated by the fire pond in the hall. The opening of external windows and the absorption of solar radiation have a greater impact on building heating.

It can be seen that by selecting the exterior windows of the watchtowers and residential buildings in the Western Sichuan Plateau during the whole life cycle, on the one hand, we can theoretically explore the relationship between the energy consumption and economy of the watchtowers and the economy in the watchtowers in the Western Sichuan Plateau during the whole life cycle, and then realize the design of the watchtowers in the Western Sichuan Plateau. Energy consumption and economic control during the entire life cycle of residential building construction can achieve good energy conservation and economic cost savings; on the other hand, good control of the window-to-wall ratio and exterior window types can make the style of the residential buildings in the watchtowers on the Western Sichuan Plateau better. A good legacy.



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