

Passive Design of Traditional Buildings in the Hot and Arid Regions in Northwest China

Yu Liu, Jing Li, Jinghua Liu and Ying Fu

Architecture Department, Northwestern Polytechnical University, Xi'an, China

ABSTRACT: This paper reviews, abstracts, and discusses some special building constitutions and features that have resulted from the traditional building design concepts, strategies and technologies, all of which have been developed and applied in response to the natural environmental conditions in the hot and arid regions in northwest China. It also briefly introduces one contemporary building project that has made efforts to apply the traditional passive design concepts. The paper aims at abstracting valuable passive design experiences from traditional buildings in hot and arid areas and providing useful references to the contemporary architectural design practice for regions under similar climate conditions.

Keywords: Hot and arid environment, passive design, traditional building, China

1. INTRODUCTION

China is a large country with many different climate variations. The characters of local traditional buildings in different regions have been restricted by their specific environment.

This paper reviews and abstracts some special building constitutions and features that have resulted from the passive design concepts, strategies and technologies in the hot and arid regions in China and discusses one contemporary building case that has learned from the traditional building experiences in the researched region.

2. HOT AND ARID REGIONS IN CHINA

2.1 Locations

The arid regions in China locate in its northwest area, including part of the Ningxia Hui Nationality Autonomous Regions and most part of the Xinjiang Uigur Nationality Autonomous Region, including the biggest desert area in China (Figure 1).

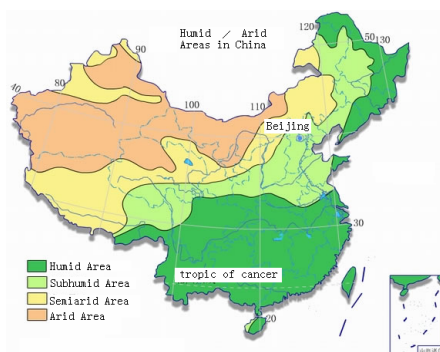


Figure 1: Distribution of the humid and arid areas in China (adapted figure, originally from <http://www.shanxi.edu.sh.cn/kejian/ziyuanku/juniorgeo/media/picture/002/images/dt18.jpg>)

This paper mainly introduces and discusses buildings in South Xinjiang, which have special features in responding to the hot and arid natural climate of the region.

2.2 Climate characteristics

The most outstanding nature environmental characteristics in the researched regions are the arid climate and the abundant radiant heat from sun [1]. The very low precipitation in these regions results in a huge diurnal as well as yearly temperature difference.

For example, inside South Xinjiang, although the annual average temperature in the whole region is between 10-13°C, the extreme high temperature in summer time can reach 48.9°C in the Tulufan basin, while the extreme low temperature in winter time can reach 51.5C in its Fuyun County. The temperature difference can reach 25C in a single day. A proverb that describes the strange and interesting lifestyle induced from the special climate feature (huge diurnal amplitude of temperature) in Tulufan is well-known in China: “wear fur coat in the morning, wear silk cloth at noon; eat watermelon around a stove (fireplace, heater)”.

The rainfall in the South Xinjiang mainly comes from the west wind from the Atlantic Ocean and the Arctic Ocean. Wind from Pacific Ocean and Indian Ocean can hardly get into this area. The annual average precipitation in Xinjiang is about 145mm, which is about 23% of that in China (about 630mm), and almost the least compare to many other places at the same latitude. In the Toksen county of Tulufan basin, the annual average precipitation is extremely low, only 4mm, while the amount of evaporation can be 30-40 times of its precipitation (Fang 2000, p56).

Solar radiation and wind in South Xinjiang and Ningxia regions are strong. Force 8 wind can be found in up to 120 days of a year. These make the land even drier. There are large desert areas in the region, and in the spring and autumn seasons, there

are often floating dust and sand storms in the plain area.

3. TRADITIONAL BUILDINGS' CHARACTERS AND PEOPLE'S LIFE-STYLES

3.1 Shade outdoor space

Adapting to the hot and arid climate in the researched areas, local people like to stay at outdoor places such as courtyards, streets and other open spaces in the summer time. In responding to this requirement, the concept of "shade spaces" is implied in the traditional buildings forms.

3.1.1 Shade spaces in the street.

The sections of many streets in the traditional districts are narrow and high—about 2.5-3 meters wide and 4-6 meters high. Because of the narrow scale of street, and the maze-like plan, not cars can be used in these districts (Figure 2). Ten years ago, when the researchers first visited the place, a wagon drawn by a donkey was still used in the area. Now many people use motorcycle instead.

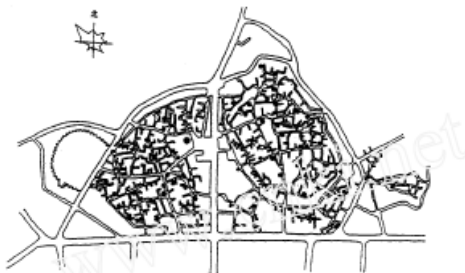


Figure 2: Maze-like streets in the old district [2]

In the traditional district and villages, local people like to build storage rooms and dry-toilet (no water flush is used) across and above the street (Figure 3). These structures are called "Guojielou". They are allocated about 10-20 meters apart along the street, and provide a series of outdoor shade spaces for pedestrians, especially for children in the community, who like to gather and play in the cool and tunnel & maze-like spaces.



Figure 3: High and narrow section with Guojielou along the street provides "shade space" for pedestrians.

3.1.2 Shade space in the courtyard

Many traditional buildings in the discussed region apply an inward layout. All the rooms are arranged around a central courtyard. The exterior walls are high, heavy and thick clay walls. They seldom have any opens or windows to the outside.

Along the three or four sides of the courtyard, there are deep roof overhangs that shade the open corridors. Inside the courtyard, there are usually vine trellises and apricot trees that helps in providing shade space, cool air, and fresh fruits for the family or even for the market[3]. In some houses, loosely weaved matting is placed 6-8 meters above the courtyard to prevent majority of the sunlight from getting through and reaching the ground of the courtyard.

3.1.3 Shade space under Aayiwang

The term Aayiwang comes from the Uigur language that means "brightness". It refers to a type of building structure with clearstories supported by four to eight columns above a central living space (Figure 4). This type of building structure is used in many South Xinjiang areas. The clearstory above the roof level works like a chimney and helps in providing natural lighting and ventilation for the underneath living space, which is mostly used in summer time. It also provides the largest, most well decorated and lighted living space for the family.

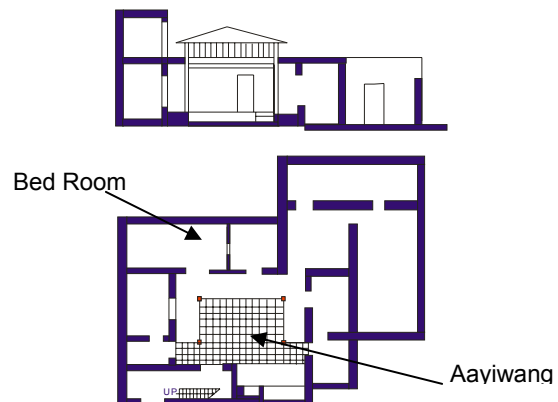


Figure 4: The plan and cross section of Aayiwang (Edited drawing from Huang, W., *Building form and climate design*. Architecture Journal, 1993 Iss.2, P12)

A 400-500mm high platform made of clay is usually placed at the living space. It is covered by beautiful handmade carpets and can be used as dining table, working desk, playground and bed at different times of a day. People work, eat, chat, dance and (children) play on the platform at daytime; and the whole family sleep on the platform at night time. Obviously, Aayiwang provides a very useful and multifunctional space for people living in the place.

3.2 Closed plan and design

The building densities in the old districts of the researched regions are usually very high. The closed layout of buildings and streets in the old district (Figure 2) can reduce both heating and cooling load

as well as protect the district from sand storm, which may happen a number of times a year in the area.

Individual houses are normally designed with windows and doors of each room only open to the shaded central courtyard. Many windows can be covered with blinds in the summer daytime to prevent solar heat gain. So the indoor spaces are often cool but dark. Some buildings have a basement that can be used as storage of bedrooms in both hot and cold seasons.

3.3 Clay and brick materials

The major local building materials in the research region are clay and brick. Because there is little rainfall in the region, most building walls are built with only clay or clay bricks. In some more important buildings, stones may be used to provide stronger and more durable bases for the clay walls above it. The heavy and thick clay or clay brick walls serve as good thermal mass that not only reduces heat transfer between indoor and outdoor spaces, but also naturally modify the indoor temperature. Such material is cheap and easily available in the region so is used in different ways and in different types of buildings. For example, it is popular in the region to use the sun-dried mud bricks to build a cubic structure with hollow-out walls that can air-dry the abundant grapes in the region (Figure 5) [4]; clay blocks are also used to build some small structures and facilities for the family, like the arch-style stairs, beds and stoves in the courtyard.

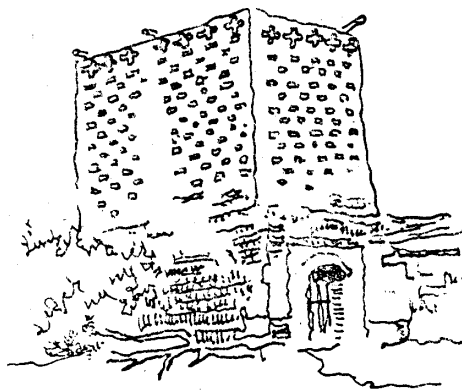


Figure 5: The cubic structure made of sun-fried mud bricks with hollow-out walls to help air-drying grapes[4]

The colour, texture and structural forms based on the clay material of traditional buildings have formed specific regional identity and feelings of belongingness for local people in the region.

3.4 Moving life style and flexible spatial design

People live in the researched region is used to a moving life style—they live/stay at different spaces in

different seasons of a year and at different times of a day[5]. For example, many traditional houses have a “winter room” and a “summer room”. The winter room is usually placed at the core of the house with a heating stove inside it and the walls are covered with heavy wool carpet. So it is the warmest place that has the least heat-lose in winter time. The summer room is usually placed next to the courtyard and has windows and doors open to the courtyard, so is easier to be ventilated in the hot summer time.

Besides moving between winter and summer seasons, people move to different spaces in a single hot summer day. For example, in early morning or late afternoon, when the air temperature is not too high, people may stay in the courtyard; in the hottest period of a day (10am-3pm), people must move into indoor spaces, preferable to the basements. At night time, people have the choice of moving up to the plain roofs of the buildings to enjoy the cool air till very late at night. Some adults may even sleep all night up there.

There is no fixed rule or regulation for designing the building spaces in the researched region. The building spaces can be designed big or small, high or low, all in responding to the moving life style and the desired functions. In other words, the “forms” are designed freely and flexible following the “functions”; in this sense, they imply and practice the “modern” design concept.

4. PASSIVE DESIGN FEATURES IN CONTEMPORARY BUILDING DESIGN

The specific climate conditions in the researched region have resulted in the special characteristic of the buildings and life-styles of people living in the place. These become part of the local culture and traditions that must be considered and respected in the contemporary building design.

One contemporary building design case that reflects the specific climate conditions and local culture is the International Fair Trade Market (IFTM) in the “national pattern and feeling street” in the Wulumuqi city.

The site of the project had been a busy commercial district in the history. According to the master plan of the city, the IFTM should be designed to demonstrate the special Uigur cultural and national characteristics of the site, and make it a landmark of the city.

The total construction area of the project is 9000m² including three commercial building complexes, a pedestrian street, one rebuilt mosque, one sight-view town, one underground car park, and a big open space (square) for outdoor performance (Figure 6)



Figure 6: The International Fair Trade Market Wulumuqi, Xinjiang, completed in 2003

To achieve the above-mentioned targets and make the building a culturally appropriate and environmentally friendly space, the IFTM follows the traditional design concepts and strategies in a number of ways [6].

- ✧ The arched corridors along the streets and the large span buildings provide shade and cool semi-outdoor and indoors spaces for people moving around the place in hot summer time.
- ✧ Domes (made of light steel and glass) are designed for the large span building blocks. Their functions are similar to the Aayiwang in traditional houses—to provide natural lighting and enhance natural ventilation for the underneath indoor spaces.
- ✧ The closed layout largely reduce unwanted heat lose in winter time and heat gain in summer time. It also reduces the influence of strong wind or sand storms to the inward open spaces.
- ✧ The external wall material is mainly local made earth-red firebricks. It has been proofed as being able to satisfy the rigorous climate conditions in the region; and it naturally fits the local building in colour and texture and so can easily fused with the local cultural characteristics and context.
- ✧ The forms, shapes and styles of the many indoor and outdoor spaces are designed flexibly in responding to the climate and cultural considerations, as well as their different functions.

This project was complete in year 2003, and since then attracted lots of interest and discussion. It demonstrates successful efforts to apply traditional building concepts and strategies, at the same time to satisfy the contemporary demands. It provides useful experience for other buildings in the same region.

5. CONCLUSION

This paper has introduced the specific natural climate conditions in the hot and arid regions in northwest China and discussed the corresponding building constitutions and features that have been developed and applied in the traditional and contemporary buildings. The passive building design strategies applied in the investigated region can be useful references to contemporary architectural design practice for regions under similar climate conditions.

REFERENCES

- [1] Chen, X.S., *The design of modern architecture in ruthless area in south Xinjiang*. Engineering Construction and Design, 2005 (11): 30-31.
- [2] Fang, Z.Y., *The geographical climatology research of the Chinese traditional ethnicgroup*. Journal of Beijing Institute of Civil Engineering and Architecture, 2000. Vol. 16 (1): 50-59.
- [3] Liu, M., *Climate and Ecological Building*. Agriculture & Technology, 2002. Vol 22 (1): 52-56.
- [4] Wang, L. and T.D. Ma, *From traditional houses of Xinjiang to climate design and ecological architecture*. Journal of Northwestern Institute of Architectural Engineering, 1994 (2): pp35-38.
- [5] Huang, W., *Building form and climate design*. Architecture Journal, 1993 (2): 10-14.
- [6] Wang, X.D., *Specific circumstances and their architectural expression* Architecture Journal, 2003 (9): 28-31.