Study on the Historical Development and Architectural Features of Independent Yaodong Dwellings with Flat Brick Arch Technique

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1. Introduction

1.1. Research Target and Background

Yaodong is one of the five famous traditional dwelling types of China. With the characteristics of the arch structure and earth sheltered, this dwelling type is widely distributed in the northern areas of Loess Plateau. While the flat brick arch technique is a kind of arch form with a 1/5~1/10 risespan ratio, which could be used for the construction of roofs or floor slabs. After the founding of the People's Republic of China, a new form of independent yaodongs using the flat brick arch technique appeared (hereinafter called flat brick arch yaodong). Under the special background at that time, this new yaodong type quickly spread and faded away during 1960s-1990s, which showed quite different stories comparing to the traditional yaodong types.

1.2. Literature Review

Yaodong matured in feudal society and became widely known since the 1980s. In China, Guo Binglu, discussed the classification and distribution of yaodongs in Loess Plateau areas. In Japan, SHIRO AOKI classified different types of cave dwellings in Loess Plateau, KATSUHIKO YASHIRO mainly took sunken yaodongs as research objects and cleared the spatial orders of courtyards. But most of them just paid attention to the sunken yaodong types.

On the other hand, research on the masonry structure technique in China during 1950s-1980s is also not mainstream. A few literature about flat brick arch are founded in the Architectural Journal. For example, Sun Fangchui analyzed the technique and construction craft of flat brick arch in his book named *Flat Brick Arch Architecture*. But all of these researches did not discuss its development process and combinations.

1.3. Research Purpose and Significance

Because flat brick arch yaodong dwellings draw no attention in the academic circle. This article studied the

historical development and architectural features of this unique dwelling type, hoping to fill up some blanks of this type and draw more concentration later. It will be beneficial to understand more about the development processes of independent yaodong dwellings and the flat brick arch technique. Thus helpful to understand more about contemporary society and to give more advice for the construction and protection of masonry heritages in different kinds of fields.

1.4. Area Study

Mizhi ancient town as a typical case of yaodong dwellings areas, two times of field researches have been given to it in October 2018 and January 2019. About over 100 courtyards were given simple visits. And 47 courtyards were given detailed investigations and mapping, among which 31 courtyards are traditional independent yaodongs built before 1949, 9 countyards are cliffside yaodongs and 7 courtyards are yaodongs built after 1949.

2. Historical Process of Flat Brick Arch Technique

According to the historical literature studies, in this chapter , the historical development of the flat brick arch technique after 1949 is divided into four different periods as shown in Figure.1.

I- Preparatory Period

First is the preparatory period. From 1949 to 1952, China was still in the economic recovery period. Also in the architecture field, most people believe that the "nation form" which comes from the Soviet is the correct direction for architecture design. At that time a lot of modern buildings with unnecessary "nation form" such as huge traditional-like roofs appeared, which cost much waste of resources.

II- Development Period

Second is the development period, which theme is saving materials and low-tech. From 1953, China started the first five-year plan. The government needed to concentrate



Fig.1 Historical Process of Flat Brick Arch Technique

resources on industrial development. Also due to the criticism on "nation form" given by the new leader Khrushchev in Soviet. This time "Saving three materials (wood, concrete, steel)" became a tough policy on all levels. On the other hand, this limited design and construction condition inspired a lot of unique low-tech construction with masonry structures at that time. Flat brick arch, along with other masonry techniques coming from the Soviet, were used in many factory constructions.



Fig.2 Flat Brick Arch Fig.3 Double Curvature Brick Vault (Xu Baichuan 1956)

III- High-tide Period

The third is the high-tide period, which theme is self-reliance and collectivism. From 1958, Chinese government started the movements of "People's Commune" in rural areas to call for collectivism and communism. Also because of the international tensions, the "Third Front Construction" movement was started and caused the industrial migration to the west. At this time an economic construction mode with the characteristics of low-tech, speedy, and collecctive construction came into being. This inspired a lot of technics standing for the spirit of self-reliance (such as rammed earth dwellings). Among them, because of the simple structure and ease for collective construction, the flat brick arch technique quickly spread and was widely used for the non-productive buildings in many areas in western China.



Fig.4 Two-Storeys Flat Brick Arch Collectivism Dwelling

IV- Degenerating Period

Fourth is the degenerating period. From 1978, China started the reform and opening up. On the one hand, with the productivity growth, low-tech buildings are no need anymore. On the other hand, with the ends of many social mobilizations and reform of the economic system, the collectivism system came to an end. This caused many changes such as the isintergration of the welfare-oriented public housing distribution system and finally caused the fading away of this flat brick arch technique.

3. Yaodong Unit with Flat Brick Arch Technique3.1 Influence from Dazhai

Dazhai is a village in Shanxi Province, where yaodongs are also the local traditional dwellings. New yaodongs builtin Dazhai were arranged like a train and were mostly built by the villagers themselves during 1963-1966. The first floor was yaodongs made of black bricks and the second floor is brick houses with red tiles. The space between the houses and yaodongs is the public area and paths for the villagers. These unique yaodong buildings showed the spirit of self-reliance and collectivism. This caused widely social mobilization effects and had drawn many study visits. In the guide book on new village planning published after this movement, it was pointed out that one of the principles of "new village" construction was "saving land and advocating storied buildings". These points contributed to the combination of flat brick arch technique with traditional yaodongs. Since mid 1960s, flat brick yaodongs gradually



Fig.5 Yaodongs in Dazhai

increased in yaodong dwelling areas.

3.2 Structure Analysis

Because of the lower rise-span ratio, the flat-brick arch also has larger horizontal force. So the thrust girder and tensile girder system are usually used to make the structure stable. In terms of the construction process, the method of the first floor is similar to the traditional independent yaodong's. Then the walls on the first floor will be used as foundations to start the construction of the second floor. First, build the brick load-bearing walls with some pre-moded holes for the cross arms. Then concreting thrust and tensile structure above them. Finally waiting for 70% of the design strength can start the construction of brick arches. Use cross arms to support the timber channels above them, and the formworks used for roof construction could move along the channels. There are two types of roof constructions shown in figure 7.



3.3 Single Building Comparative Analysis

Traditional independent bricks yaodongs usually use black bricks for the arches and stones or bricks for the walls. While flat brick arch yaodongs use bricks for the construction of walls and arches, and the second floor could be constructed with the first floor together or later. Because the second floor causes more load, so usually the two sides of the walls will be made thicker or used as the staircase to balance the thrust. Traditional yaodong usually has many facade decorations such as stone dougong or timber canopy, but flat brick arch yaodong is quite simple, only with some slogans or symbols. **4 Flat Brick Arch Yaodong Institution Community**



Fig.8 Yaodong Units Comparison

Flat brick arch yaodong dwellings were mostly used as stations for public institutions (Central County Committee, Water conservancy bureau, broadcasting station, agricultural bureau, etc). This reflected the influences by the unit system under the planned economy in China.

4.1 Plane Classification

Due to the scale of the units, there are two types of arrangements of them. The first one is the "I" type which was mainly used for dwellings. On the one side of the yard lays the train-style yaodong dwellings which could be singlestoried or double-storied. On the other side are accessory occupancy such as kitchens. One household usually included a cave on the first floor and a room above it. The former was used as a livingroom and kitchen while the latter as a



Fig.9 Yaodong Countyard System

bedroom. The second type is the "L" type which was mostly used for offices of these institutions. Almost all the dwellings in this type are double-storied flat brick arch yaodong dwellings. Usually, this type of institution has a large scale and also needed space for production activities.

4.2 Case Study

This chapter gives a case study to No.28 in West Street. This yard was built in 1970 as the working place for agricultural machinery bureau, which is the first independent yaodong dwelling using the flat brick arch technique in Mizhi ancient town. This "L" type yard consists of two slides of train-style yaodongs, one with 7 rooms on one floor and the other with 9 rooms. The middle room of the 9-caves dwellings on first floor is used for the main gate for the yard. On the northwest are the buildings for machine uses.



Now about 70 people living in this unit community. Among them, 3 households are the former workers belonging to the agricultural machinery bureau while the other 17 cases are the migrant tenants. Not like the traditional yaodong quadrangle yards, people gathered because of blood relationships in feudal society. People in these unit yards were just workmate relationships and the buildings were also free to use. Finally in 1998, with the moving away of the institution and end of the welfare-oriented public housing distribution system, many migrant tenants flooded here and the dwellers should pay the rent to the institution.

5. Conclusion

Conclusions are drawn in the following:

(1) The historical development of the flat brick arch could be divided into four different periods, and this technique meet the main needs in II and III periods, which caused the quick spreading of it.

(2) As a symbol of self-reliance and collectivism. Flack brick arch yadongs are basically with odd number of caves over 7 and assumed to be constructed mainly in the late III and early IV periods. Double-storied yaodong types were assumed to come from the influence of Dazhai.

(3) Flat brick arch yaodongs were almost used as stations for public institutions. In many cases which are no longer used for institutions, migrant tenants occupy the dominant status.

Above all, the flat brick arch yaodong is a modern type of cave-dwelling that combines the flat brick arch technique with the independent cave dwellings. Under the background of saving three materials and low-tech construction, the flat brick arch technique quickly spread. Then after 1964, under the influence of Dazhai it combined with traditional yaodongs and became a symbol of self-reliance and collectivism construction for public institutions. Finally after the reform and opening up in 1978, On the one hand, with the producticity growth, low-tech buildings are no need anymore. On the other hand, with the ends of people communes and start of the economic system reform, collectivism system came to an end. This weakened the unit institutions and welfare-oriented public housing distribution system and finally caused the fading away of the flat brick arch technique and flat brick arch yaodong dwellings.

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