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# Research on the Green Development of Space Defense System and Construction Technology of Great Walls in Shahukou

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**Abstract.** To study the characteristics of green development of the ancient Great Walls, this paper studies the space defense system in Ming and Qing dynasties and construction technology of Shahukou by means of literature review and on-the-spot investigation. The conclusions are as follows. The ancient Great Walls in Shahukou is a large and deep spatial structure which composes of Shahukou pass of Great Walls, Shahu fortress, and different types of piers. The attackers need to occupy city towers over city gates in Shahu Fortress and corner tower over Mamian pier, while the defenders need to carry out fire prevention and anti-collision work for the gate and gate hole in Shahu Fortress. Rammed materials has experienced many stages, such as ginger stone and yellow mud, grass mud, tabia, glutinous grain pulp tabia, and glutinous grain pulp mortar. Timber construction, timber component, and timber formwork were existed timber in the construction process in ancient Great Walls. The reason why large area of covered bricks lost was that a through joint was formed between the brick layer and the rammed soil.

## 1. Introduction

The ancient Great Walls of Ming Dynasty in Shanxi Province remains in 8 cities which contains 40 counties or districts. The amount of defense location which contains enemy towers, beacons and other small independent constructions are 4276 on the record. The existing sites have a long time span from Warring States Dynasty to Ming Dynasty. [1-3] Because of military defense attributes, it belongs to one of the most vulnerable ancient constructions. The existing ancient Great Walls are in the situation of constant destruction. Therefore, it's urgent to protect and repair them.

To study the characteristics of green development of the ancient Great Walls, the research object in this paper is the construction complex of ancient Great Walls. By means of literature review and on-the-spot investigation, it studies the space defense system in Ming and Qing dynasties and construction technology of Shahukou.

## 2. Space defense system

### 2.1. Great Walls military system in Ming and Qing Dynasties

The history of Great Walls in Shahukou can be divided into three periods. They are military defense period, military defense and trade period, and ecological protection period. [4] The construction



complex of Great Walls has existed since ancient times. However, because of its typical military consumption feature, the Great Walls often needs to be rebuilt. The latest time to build the Great Walls on a large scale was in Ming Dynasty, so was the Shahu fortress. Therefore, it's necessary to study the military system in Ming and Qing dynasties.

In order to defend against the attack from foreign nationalities such as Tatar and Wala, the Ming government divided the Great Walls into nine defense areas, which is called “Nine Strategic Towns”. In this military system, Zhen City has the highest level, followed by Lu City and Suo City. And Fortress is the smallest defense unit.

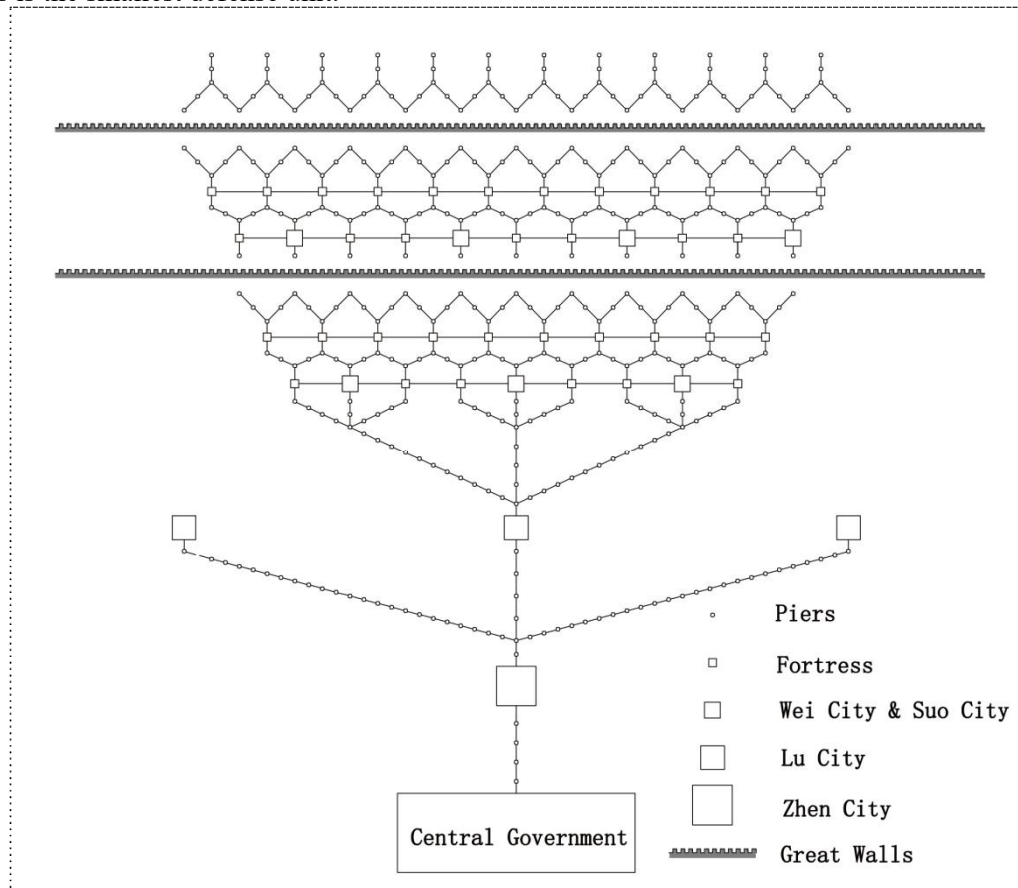


Figure 1. Hierarchy of military system in Ming Dynasty

When the defense line in Early Qing Dynasty moved northward to Guihua City, the defense level of Shahukou was adjusted downward. In Middle Qing Dynasty, Shahukou assumed the tax mission but no military one, which contained only 100 soldiers to help taxation.

## 2.2. Space defense system of the ancient Great Walls in Shahukou

The main reason why Chinese Great Walls has stronger defense than foreign great walls is that it has a series of large deep space defense system. Taking Hadrian Great Walls in Britain and Germanic Great Walls in Germany as examples, both of them belong to linear defense system. Comparing with Chinese Great Walls, the length of the two great walls is relative short, the supporting military constructions have few levels and short depth, and the defense system is relatively weak.

The ancient Great Walls in Shahukou is a large and deep spatial structure which composes of Shahukou pass of Great Walls, Shahu fortress, and different types of piers.

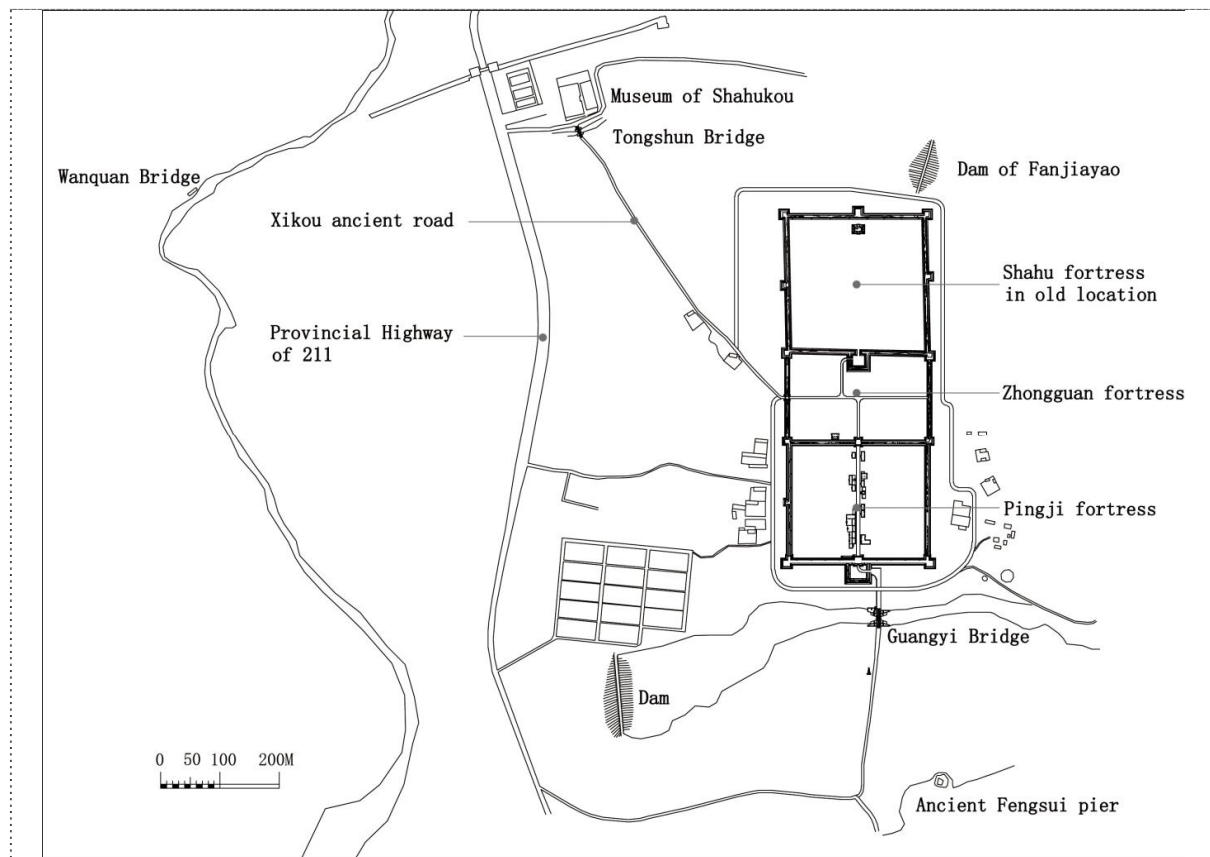


Figure 2. General layout of ancient Great Walls in Shahukou

Shahukou pass of Great Walls includes pass constructions, linear walls of Great Walls, and Mamian piers.

Shahu fortress is subordinate to Datong Zhen City. It stands at the front of the Youwei Lu City. It's the first defensive front for Ming government.

All types of piers have the fundamental function of transmitting military information. Most of them can be called Fengsui. With the continuous development of construction requirements, other pier forms were extended, such as Ditai, Hou, etc. In the process of transmitting information, the piers are the key to form a large deep space defense system for the ancient Great Walls.

### 2.3. Space defense part in Shahu fortress

As a part of the defense system of ancient Great Walls in Shahukou, research on space defense part in Shahu fortress is needed.

In the campaign of the cold weapon era, if the attackers want to win, they need to cross the moat, occupy the height of fort walls, break through the city gate, and garrison in the city. Combined with the spatial structure of Shahu fortress, we can see that the moat, the height of defense construction, and city gate are important parts in spatial defense part.

The attackers need to occupy city towers over city gates in Shahu Fortress and corner tower over Mamian pier, while the defenders need to carry out fire prevention and anti-collision work for the gate and gate hole in Shahu Fortress.

## 3. Construction technology of Great Walls and fort walls

### 3.1. Construction materials

In the construction of ancient walls, the commonly used materials are soil, stone, brick, and wood.

*3.1.1. Soil.* The Great Walls and fort walls are very thick. And the main material of the ancient walls is rammed soil. In the early stage, ginger stone and yellow mud were the most widely used in it. Later, straw rods or crushed stones were added to the mud to enhance its adhesion, which was called grass mud. Gradually, people invented the solid and durable tabia, which was made of clay, sand and lime.

In order to increase the tamping strength of the walls, people mixed grain pulp into the mixture to form the glutinous grain pulp tabia. At the same time, to adapt the masonry structure with better strength, the glutinous grain pulp mortar emerges as the times require. It mixed hydrated lime or limestone mixture with grain pulp. And also, tung oil, alum and other materials are added into glutinous grain pulp tabia and glutinous grain pulp mortar to strengthen its waterproof and impermeability effect.

### *3.1.2. Stone.*

In the process of ancient wall construction, the structure of “paving stone slab below and paving brick above” was adopted. The aim was to prevent the wall foundation from crispness and alkalization. The wall foundation was designed with strip stones or block stones. Some walls were built with stone, but the scale was not too large.

There are 5-6 floors in Pingji fortress. The corner stones and footstones are made of bluestone with a length of 700-750mm and a width of 200mm and a height of 200mm. Some parts are damaged, but we can still find out the same regulation.

### *3.1.3. Brick.*

During the Ming and Qing Dynasties, the technology of firing bricks was improved obviously. At that time, the technique of bricking walls was appeared outside the Great Walls and fort walls.

The existing bricks in Shahu fortress were hand-made water embryo green brick. There were no any inscriptions on the brick. Therefore, we cannot find out the original kiln.

The regulation of Shahu fortress brick was different from that of official kiln. The Mian(length) was 300mm. The Lei(width) was 180mm. And the Tou(height) was 70mm.

*3.1.4. Timber.* Three places were existed timber in the construction process in ancient Great Walls. They were:

- Timber construction on Great Walls and fort walls. It mainly referred to the city tower.
- Timber component. It included timber components of city gate, timber components in rammed soil walls, and timber components in foundation.
- Timber formwork. It's the formwork for city construction, which was basically timber, such as the traditional technique of timber formwork ramming, the one of rafter binding and ramming, etc.

## *3.2. Ramming technique*

The ancient walls were constructed by manual ramming. In the construction process, traditional craftsmen used scaffolds. The maximum height of rammed walls can reach 10 meters for the hardness limitation of soil material. The height can be increased appropriately when stone was used, but the stone walls were not too high actually when considering costs.

Before Ming Dynasty, the main ramming technique was timber formwork ramming. While after that, the main ramming technique was rafter binding and ramming. Compared with the above two ramming techniques, it can be seen that:

- The construction method was more scientific and economical in formwork of rafter binding and ramming. The formwork of timber formwork ramming was short, while the one of rafter binding and ramming was long.
- Due to the limitation of manual ramming strength, the overall rigidity of the walls was poor. While the one of rafter binding and ramming walls was strong.



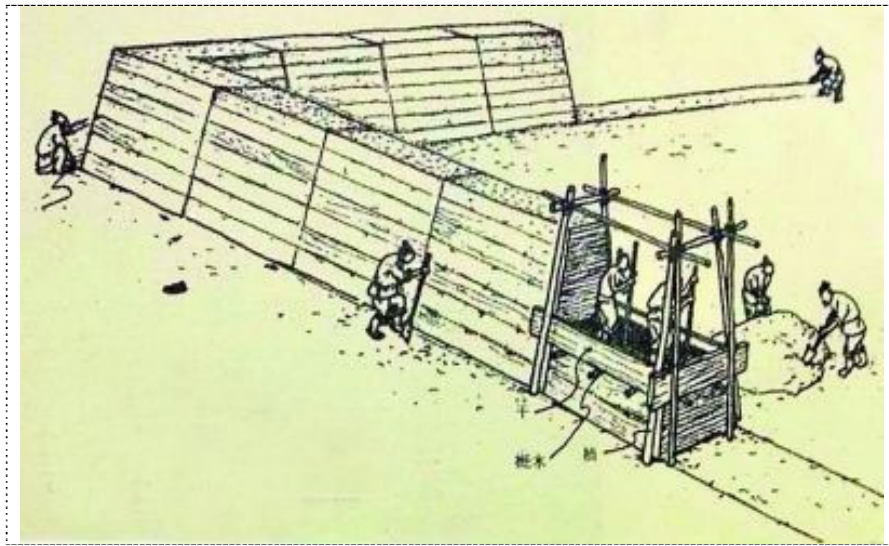


Figure 3. Technique of timber formwork ramming

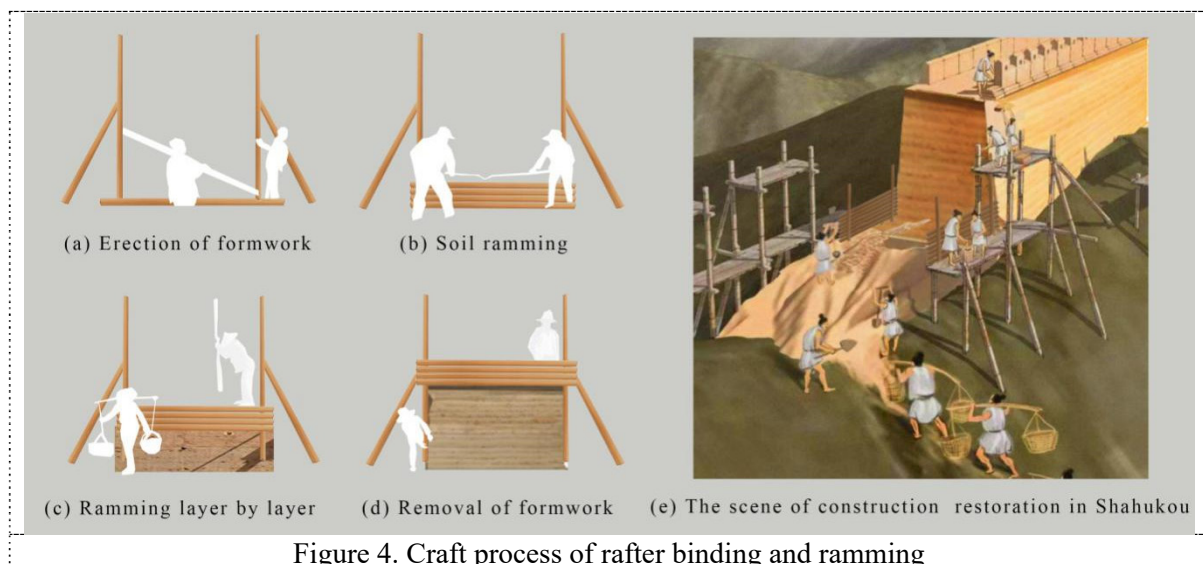


Figure 4. Craft process of rafter binding and ramming

### 3.3. Bricking walls technique

The technique of bricking walls emerged in Middle Ming Dynasty. Bricks can be divided into two layers. They were inner bricks and outer bricks.

After 9 years of the interval between the tamping and bricking, a through joint was formed between the brick layer and the rammed soil. It's also one important reason why large area of covered bricks lost.

### 3.4. Waterproof technique

As a typical soil material construction, it's necessary to take waterproof measures at the top and both sides of the Great Walls and fort walls.

The two sides of the wall were covered with bricks, which was the typical waterproof treatment.

At the top of the Great Walls and fort walls, 500mm thick 37 lime soil was laid on the rammed soil wall for tamping and levelling. Finally, the bricks were laid on top.

Most of the fort walls were inclined one side, and only a few places were inclined from middle to outside in Shahu fortress.

#### 4. Conclusion

This paper studies the space defense system in Ming and Qing dynasties and construction technology of Shahukou. The conclusions are as follows.

- The military function of Ming Dynasty was the strong. The defense level was lowered in early Qing Dynasty. And the trade function was enhanced and the military function was decreased in middle Qing Dynasty.
- The ancient Great Walls in Shahukou is a large and deep spatial structure which composes of Shahukou pass of Great Walls, Shahu fortress, and different types of piers. Shahukou pass of Great Walls includes pass constructions, linear walls of Great Walls, and Mamian piers. As the first defensive front for Ming government, Shahu fortress is subordinate to Datong Zhen City, which stands at the front of the Youwei Lu City. The piers are the key to form a large deep space defense system for the ancient Great Walls.
- The attackers need to occupy city towers over city gates in Shahu Fortress and corner tower over Mamian pier, while the defenders need to carry out fire prevention and anti-collision work for the gate and gate hole in Shahu Fortress.
- Rammed materials has experienced many stages, such as ginger stone and yellow mud, grass mud, tabia, glutinous grain pulp tabia, and glutinous grain pulp mortar. Timber construction, timber component, and timber formwork were existed timber in the construction process in ancient Great Walls.
- The reason why large area of covered bricks lost was that a through joint was formed between the brick layer and the rammed soil.

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