D I S S E R T A T I O N

Wooden granaries of South China:

Building craft and its determining factors

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Zusammenfassung:

Ziel meiner Forschung ist eine Untersuchung verschiedener Bautechniken von reinen Holz-Getreidespeicher in Südchina vorzulegen. Als eine Art landwirtschaftliches Nebengebäude war es im akademischen Bereich lange Zeit vernachlässigt worden. Aufgrund der Bedeutung und des Wertes der darin gelagerten Produkte steckten die Zimmerleute jedoch normalerweise die gleiche oder sogar noch größere Mühe und Begeisterung in den Bau eines effektiven und langlebigen Getreidespeichers verglichen mit der Errichtung eines Wohnhauses. Zimmerleute mit unterschiedlichem kulturellem Hintergrund entwickelten verschiedene Varianten einen Getreidespeicher unter verschiedenen einschränkenden Bedingungen zu bauen. Die Vielseitigkeit der in Holz gebauten Getreidespeicher Südchinas erlaubt uns den interaktiven Einfluss zwischen Umwelt und sozioökonomischen Faktoren sowie Bautehnologien zu studieren. Die primären Fragen meiner Forschung sind: Welche Faktoren bestimmten die Bautechnologie? Welche Faktoren förderten Veränderungen in den Bautechnologien?

Meine Dissertation gliedert sich in drei Hauptteile: 1) Einführung, 2) historische Getreidespeicher, 3) Erfassung und Analyse verschiedener Getreidespeicher und deren Gebäudetechnik in vier sehr unterschiedlichen Regionen Südchinas.

1) Im Einführungsteil erkläre ich einige grundlegende Überlegungen: Anforderungen an einen effektiven Getreidespeicher, die Eigenschaften von Naturholz und die Herausforderungen, denen sich Zimmerleute beim Bau eines Getreidespeichers aus Holz in der Vergangenheit stellen mussten. Als nächstes gebe ich einen Überblick über Südchina, wo meine Forschung angesiedelt ist. Die besonderen klimatischen Bedingungen förderten die weite Verbreitung von Holz-Getreidespeichern. Es folgt ein Überblick über meine Forschungsmethodik, die den Leitfaden dieser Dissertation festlegt. Das Kapitel schließt mit einem Literaturüberblick.

2) Die Auseinandersetzung mit historischen chinesischen Getreidespeichern ermöglicht es, basierend auf einer Reihe von archäologischen Ressourcen und historischer Literatur, den Entwicklungsprozess der Bautechnologie von Holz-Getreidespeichern nachzuzeichnen. Die Forschung an historischen staatlicher Getreidespeichern bringt ans Tageslicht, wie politische Macht die Bautechnologie beeinflusst hat.

3) Teil 3 erfasst und analysiert verschiedene Getreidespeicher und deren Bautechnologie in vier unterschiedlichen Regionen Südchinas. Dies ist der Kernteil dieser Dissertation. Er basiert auf meinen Felduntersuchungen von 2014 bis 2016. Die Arbeit besteht aus detaillierten Messungen und Analysen verschiedener Studienobjekte und untersucht mit ihnen in Zusammenhang stehende beeinflussende Bedingungen. Auf Basis von selbst durchgeführten Messungen und Interviews mit lokalen Zimmerleuten untersuche und dokumentiere ich den Bauprozess, die Konstruktionsdetails und den technologischen Wandel verschiedener Arten von Getreidespeichern. Diese Studie zielt darauf ab, alle möglichen Einflussfaktoren der Gebäudetechnik abzudecken: Umweltfaktoren (Jahresniederschlag, Regenzeit, Gelände, Vegetation usw.), sozioökonomische Faktoren (Familienindustrie, Familiengröße, Arbeitsteilung innerhalb der Familie, regionaler Sicherheitsstatus, Landverteilungssystem usw.), Agrartechnologie (Grundnahrungsmittel, Ernteprozess usw.), Bautechnologie (Bauprozess, Werkzeuge des Zimmermanns, usw.). Die Analyse der Getreidespeicher zeigt, dass ihr Aussehen neben sozialen und kulturellen Einflüssen Resultat vielfacher Faktoren ist, vor allem Aufstellungsort, Gestaltung, Bauprozess und Konstruktionsdetails.

Abstract:

This study aims to explore the diverse building technologies of wooden granaries in South China. They are a type of agricultural outbuilding that has long been neglected in the academic field. However, due to the importance and value of the items stored inside, carpenters usually contribute the same or even greater effort and enthusiasm into building an effective and durable granary compared to building a dwelling. Carpenters with different cultural backgrounds developed different ways to construct a granary under various limiting conditions. The diversity of wooden granaries in South China provides an opportunity to observe the interactive influences between environmental and socio-economic factors as well as building technologies. The main questions of my research are: Which factors determined the building technology? Which factors promoted changes in building technologies?

My dissertation can be divided into three major parts: 1) introduction, 2) historical granaries, and 3) records and analyses of different granaries and their building technologies in four entirely different regions of South China.

1) In the introduction I explain several basic considerations: requirements of an effective granary, properties of natural wood, and challenges faced by carpenters in the past when building a wooden granary. Next I offer an overview of the study's background concerning South China, where special climate conditions promoted the wide distribution of wooden granaries. This is followed by an outline of my research methodology formulating the guideline of this dissertation. The chapter concludes with a literature review.

2) The study of Chinese granaries' history allows to draw the development process of wooden granaries' building technology based on a series of archaeological resources and historical literatures. The research of historical state granaries reveals how political power influenced building technology.

3) The third part records and analyses different granaries and their building technologies in four distinct regions of South China. Representing the core of this dissertation, this section is primarily based on my field investigations from 2014 to 2016. It consists of detailed measurements and analyses of different study objects and investigation of influencing related conditions. Based on first-hand measurements and interviews with local carpenters, I investigate and document the building process, construction details, and technological alterations of various types of granaries. This study aims to cover all possible determining factors of granaries' technology: environmental factors (annual precipitation, rainy season, terrain, and vegetation), socioeconomic factors (family industry, family size, family labour division, regional security status, and land allocation systems), agricultural technology (food staples and harvest processes), building technology (building processes, carpentry tools). The analysis of granaries demonstrates that granaries' appearances are a result of multiple factors, foremost their location, layout, building process, and construction details next to social and cultural influences.

Contents

1. Introduction

Since the Neolithic period, when human beings began to settle into lives dependent on agriculture to feed their families, people have required a dedicated space for food storage. People needed to store each harvest properly to avoid potential food shortages between seasonal harvests. This requirement is suspected to be the origin of the granary, one of the most ancient buildings types in the world.

A granary is a structure built for storing cereal grains. Some granaries are combined with other functions, and they can be used also to store items such as honey. The Chinese word *Cang* (仓) is generally used to designate "granary". This word was first introduced during the Shang dynasty (ca. 1600–1046 BC). In the oracle bone scripts of that period, this term was usually written as  . The shape of the letter represents a small building standing on a foundation. This might represent a type of small wooden granary prevalent at the time.

The granary can be an underground structure such as a pit, or an aboveground building or a specific room in a building. This is mostly determined by climatic and geological conditions. Given the different climate areas in China, the shapes of ordinary granaries usually vary between North China and South China. Archaeological findings show that underground pits have been the most common storage method in North China since the early Neolithic period. Whereas in warm and humid South China, granaries are typically aboveground buildings with an elevated floor.

Wood used to be the most common material used for building private granaries or mid-size community granaries in South China during its pre-industrial era[1]. This was due primarily to South China rich resources of forest, and also to a series of advantages of using wood as a building material. One principal advantage of wood is its high hygroscopicity, which helps to keep the internal humidity of a wood granary to stay constant within a certain range. This can suppress the deterioration process. The choice of material for a traditional granary could be also related to its properties. When building a large state granary in the same region, fire-resistance was the priority requirement. Thus fireproof materials such as rammed earth or brick became the typical materials used for building such kinds of large granaries.

According to my investigation of the wooden granaries of South China between 2013 and 2016, traditional wooden granaries are still

1. Pre-industrial era of China: After the advent of the Industrial Revolution in Western countries in 1750-1850, China remained in a Pre-industrial state until the late 1970s. In 1952, 83 percent of the Chinese workforce were employed in agriculture (Anton Cheremukhin, 2015, p. 12). Quite a few mechanical tools were used in agricultural activities and construction work in most of the Chinese countryside before the 1960s. A series of proto-industrial efforts were made during that time. Since the 1960s, more mechanical tools such as threshing machines, milling machines, and mechanical saws were introduced into villages. The change of policy in 1978 forced to many farmers to leave their fields to work in factories. The strict control of rice prices, reduction of per capita arable land and improvements in the national transportation system exacerbated this process.

preserved in some remote mountainous areas in South China. While on most of plain areas wooden granaries have already vanished due to the modernization process and the introduction of new materials in these areas (王若兰, 2006, p. 50) (朱邦雄, 2006, p. 38). The persistence of granaries there can be explained by the following factors: poor local traffic development and the people living there. The more remote the area, the more consequently only members of ethnic groups settle there. In order to keep a certain amount of independence, the people intend to keep their traditions in self-sufficient communities.

These remaining rural wooden granaries in South China present a rich diversity in their appearance. (Fig. 1.1) The conventional location for a wooden granary varies from place to place: in some areas, granaries are separate buildings, located far away from residential areas. In other areas, granaries are sometimes located inside dwellings. The size of wooden granaries can also vary: some granaries are no more than 2 meters high, while some granaries can reach a height of four stories. The construction methods for granaries also vary from one region to another: granaries in some areas are log constructions, while granaries in other places are skeleton structures. Apart from these structures, the type of wood, carpentry tools, and many other details differ in traditional granaries of different regions.

Nevertheless, the main principles in building these wooden granaries are generally the same: to reduce the possible loss of stored grain during the storage period. The threats to the stored grain are many: humidity, fire, pests, humans, and so on. Therefore, it has never been easy to achieve completely the expected task of granaries, and it was especially difficult in the pre-industrial era.

A granary is a context-sensitive kind of building. The building technologies of wooden granaries are usually connected to a certain place and a certain cultural background; thus, their building forms usually present markedly regional features. The study of the wooden granaries of South China can provide further information about how carpenters develop a specified building technology to balance various surrounding environmental conditions, restricted building technology and multiple functional goals.

Fig. 1.1 Wooden granaries with different forms in South China

1.1 Research background

Most of the remaining wooden granaries of China are concentrated in the mountainous areas of South China. Given modernization processes in the past few decades, nearly all wooden granaries vanished in plain areas. The general decrease of per capita field occupation after the 1970s also caused some farmers to pay less attention to building suitable granaries. The traditional wooden granaries were gradually replaced by plastic woven bags or steel boxes or some other types of modern materials (王若兰, 2006, p. 50; 朱邦雄, 2006, p. 38). Even in the mountainous areas, more and more farmer families began to abandon their old wooden granaries and use new granaries made of modern materials. One important reason for this transition is cost. New granaries are much cheaper than are traditional wooden granaries. However, many farmers continue to insist on building and using wooden granaries; some believe that wooden granaries are adapted better to the local environment and, when used properly, can effectively delay the inevitable deterioration of the stored cereals[2].

2.In my interview with the farmers from Southeastern Guizhou, they complain that grain stored in steel granaries is prone to mold in a short period. This can be related to the high humid local climate.

1.1.1 Requirements to be met by a wooden granary

1.1.1.1 Challenges of building a granary

Due to the importance of cereal grains, properly building an effective granary is never easy, and it was especially difficult with pre-industrial technology[3]. When people need to build a granary themselves, they usually do their utmost to build a shelter to protect stored cereal against potential threats and to reduce the loss of grain during storage. Meanwhile, such a construction is always built according to the restricted building technology of the period and region.

3.Vacuum technology and storing grain in anaerobic condition are the current most advanced storage technologies in nowadays. Both of these storage methods need high industrial level.

For the stored grain, the most common threats from outside are detailed below.

i. High moisture

High moisture is usually accompanied by high temperature in South China. Both are primary reasons for the germination of stored grain and the growth of mildew in granaries. Since people believe that cereal grains with husks can be stored longer than can hulled grains, cereals stored in granaries always left with husks. In words, stored cereal grains are still seeds. Even in a dark and enclosed environment, the progress of the cellular respiration of these cereal grains can continue, by offering oxygen, suitable moisture, and temperature. The continuing cellular respiration would release more moisture and heat in the granary, thus accelerating the germination process of stored grain and leading to their deterioration in a short time. Since vacuum containers were hard to produce in a pre-industry society, what people could achieve to prevent this unfavourable result in the past was to reduce the inner moisture and inner temperature of their granaries. In North China, people usually stored their cereal grains in pits. These underground pits can generally provide a proper storage environment that is drier and colder than the conditions above ground. However, most regions of South China are much more humid and rainy than in North China. The inner humidity in underground structures in South China can thus be also quite high, so the people of South China usually found other solutions.

Reducing inner humidity by promoting interior air ventilation is an effective solution historically used in large granaries. Adding ventilation windows in granaries is one common way to create such ventilation. However, this method has a potential risk: pests such as birds and insects can easily enter the granary through these windows. Thus, people usually had to place bamboo nets on these windows. Such a method can be found in the time of the Han dynasty (for further, see section 2.4.1).

To build an ordinary rural granary, South Chinese people were inclined to build an enclosed granary without windows. Wood thus became the ideal building material for such granaries. Due to the capillary action of wood, the moisture produced by the germination process of the stored grain can be released into the outside air through wooden walls. Therefore, people are inclined to promote ventilation surrounding the granary. The wooden floor of these granaries is usually elevated from the ground, thus promoting ventilation beneath the grain stacks. Wooden granaries are requested to be located in windy and high places according to the traditions of some regions. This choice is thus also a measure for promoting the air ventilation around the granary.

On the contrary to wood, in an enclosed granary with airtight materials such as brick or metal, the cellular respiration of stored grain would slowly increase the humidity level in the granary and then accelerate the deterioration process. Such complaints have been made even among some modern-day Dong farmers who are using steel granaries.

ii. Fire

Fire is the most dangerous threat for stored grain, as it can destroy all staple food reserves. This destruction is especially dangerous for large granaries such as state granaries or community granary-groups. In the worst case, granary fires can lead to famine or defeat in war. One famous example of such a military defeat is the *Battle of Guandu* (200 AD), which Cao Cao(曹操)[4] won by burning down the

4.Cao Cao(曹操, 155-220): A Chinese warlord and the penultimate Chancellor of the Eastern Han dynasty who rose to great power in the final years of the dynasty.

granaries of his adversary. As a result, the major building materials of large granaries such as state granaries are legally mandated to be built with fire-proof material such as brick, stone, and rammed-earth walls. This rule had been specified in the building codes of the state granary since the Tang dynasty (618–907) (for further, Section 2.5). However, most traditional fire-proof wall constructions are more or less airtight. Thus, these designs always accompany raise for ventilation problems. Addressing this problem increases the complexity of the construction. Thus, most farmers of South China have insisted on using wood to construct the walls of small granaries. In respect to the fire-prevention requirement, they developed diverse methods. Locating granaries in places far from dwellings with fire sources is the most common way to prevent fires . Villagers of some places even excavated ponds and built granaries above them. Such an example is Dengcen, as shown in Section 4.3. In some Han villages, people put their wooden granaries inside of their dwellings, and chose to enclose rooms with fire sources, such as a kitchen, with fireproof materials.

iii. Pests

There are three common types of animal pests for granaries in South China: rats, birds , and insects.

Rats can break wooden walls with their teeth. Thus, farmers usually find different ways to stop them from approaching the walls of their wooden granaries. Stairs of wooden granaries with elevated floors are usually moveable, in order to prevent rats from climbing into the granary through them. Mouse guards were developed with the same considerations in some regions.

Birds can intrude into granaries through openings in granaries. People usually needed to protect ventilation windows with nets or fences. For the same reason, carpenters must also be also concerned about the sealing of ceilings and walls of granaries.

Insects mainly emerge from the grain stacks. They can not only consume some stored grain but also pollute the rest of it. Much of the loss of world grain in storage has been thought to be caused by insects (DPIRD, 2018). Appropriate measures to limit infestation in granaries have to be found: c leaning cereals before storing, cleaning the inside of the granaries before use, and keeping the inner temperature and moisture at a low level. In some areas, such as a Yao[5] village, Dongmeng, people smoke their empty granaries before the harvest period every year. They see this measure as a form of pest control.

5. Yao people(瑶 族): Its majority branch is also known as Mien. They live in Southwestern China, North Thailand, Laos and Vietnam. There are several distinct groups within the Yao nationality, and they speak several different languages.

iv. Humans

Humans represent a threat that is difficult to control. They may steal grain from a granary or even burn a granary down. A common countermeasure to human sabotage is to conceal the granary at a secret place or a place that is difficult to reach. Han people and Tibetan people were all inclined to place their granaries inside their dwellings, in order to stop strangers from snooping. Concerning granaries located far from their dwellings, people have developed diverse measures to guard them. Some people built fences outside granaries for protection, while others added barriers on the path to their granaries. For instance, some Dong people use moveable single-plank bridges as paths leading to the entrances of their granaries.

Doors are the most vulnerable part of the granary, as they are movable, so carpenters usually made a great effort to build strong doors and a strong locks granaries. Some places use a kind of special wooden wedge to lock granaries. To open such a lock, people need to hit the wedge forcefully with a wooden mallet. The process produces large noise, and villagers can then realize someone is opening the door of a granary. This method simply and effectively protects granaries placed far from dwellings.

Apart from these external factors, deformation of the structure can also lead to the loss of stored grain if the granary's construction is improper.

The side thrust from the stored grain is the main reason for the deformation of the structure of a granary. The heavy load of the stored grain not only produces downward stress on the supporting structure but also raises side thrust on the walls of the granary. The higher the stack of stored grain, the larger the side thrust. The ancient Roman stone granaries had thick stone walls and large buttresses against the inner side thrust (Rickman, 1971, pp. 2,3). Wooden granaries had to deal with side thrust by means of ties and trusses in the structures. Under this requirement, a log construction is an ideal structure for granaries. However, building a log granary requires much more timber than does a skeleton structure of the same size. Carpenters thus developed diverse reinforcement methods to confront side thrust in wooden granaries.

Shrinkage and warp of wood walls and floors is another important reason for the loss of stored grain in wooden granaries. We will discuss this problem in the next section.

In summary, a granary faces diverse threats. Under conditions of restricted technology in the pre-industrial society of South

China, building an ideal granary perfectly to preserve grain against various threats was nearly impossible. Some technical solutions can deal with more than one threat to a granary, while other technical solutions aiming at different problems might conflict with each other, such as using brick walls in granaries. In addition, the increasing complexity of the construction due to the multi-function requirement also raises the possibility of structural failure.

1.1.1.2 Wood as the main building material for a granary

With wood as the major construction material of a granary, one principal advantage is the material's hygroscopicity. As a natural polymer material, wood can absorb moisture from the air when the moisture content of wood is lower than in the air. In the opposite case, wood releases moisture to the air. Thus, in a granary enclosed by wood, the moisture produced by the germination process of the stored grain inside the granary can be released to the surrounding air according to the capillary action of wood. This function is extremely important for granaries located in humid areas, where the germination process of the stored grain can be quite active.

Certain disadvantages of wood in building a granary are also evident.

i. Flammable

Wood is a flammable material that burns very well. This property is in stark contrast to the expectation for a granary. Thus, large state granaries throughout Chinese history rarely used wood as for wall construction. When people did have to use wooden granaries to store large amounts of grain , they developed diverse fire-prevention methods.

ii. Permeable

Permeability is a property of wood which is deeply related to its hygroscopicity. In some situations, permeability can be an advantage, and in others, a disadvantage. When the wooden outer surfaces of a granary are made wet by rain, it's the inner humidity of a granary easily increases. This moisture might accelerate the deterioration process of stored cereals. Wooden granaries need to be protected against rain.

iii. Deformable

Wood generally will deform slowly during its drying process. This is a key factor relating to the building technology of a granary. After logging, the sap of the trunk evaporates slowly. This evaporation leads to a reduction of the volume of the wood . Through a natural air-drying method, the volume change of wood usually would be quite stark in the first two years and can last for the next several years or even decades. When a fresh cut log was cut into planks during the construction process, the shrinkage of wood in the subsequent years caused a significant reduction in the plank's width. According to F. Kollmann, a fir plank's width can decrease by 3.8% in the transition from green wood to a bone-dry state. The lengthwise reduction is much less. In the past, most logs were used one to three months after being felled. They had not yet reached the bone-dry state when they were used in the construction work. This means when several wooden planks were assembled together to form a floor or a piece of wall, gaps would occur between planks due to the shrinkage process. For granaries, these gaps present a serious problem, leading to loss of stored cereals in most cases. Carpenters were thus in need of an effective solution to deal with this unavoidable natural deficiency.

iv. Size limitation

The dimensions of the wood used in the construction work mostly were limited by various factors: the size of the tree, the age of the tree, the climate, transportation conditions, and so on. These limitations in format are expressed the variety of granary structures in different areas.

Finally, we should not lose sight of locally characteristic building traditions. Building tradition usually varies according to different areas and different cultural backgrounds. In this context , traditional carpentry technology of a certain region had a direct effect on how local carpenters built a wooden granary.

i. Selection of wood

People from different regions might choose different species of wood to build their granaries. The properties of wood differ by species. For instance, the shrinkage rates of hardwood and softwood differ during the drying process. When using softwood to build a granary, carpenters usually need to care more about shrinkage, for example. Hardwood shrinks slower than softwood, but it is generally more difficult to process.

ii. Carpentry tools

Carpentry tools are a key factor in carpentry technology. The tools determine the types of tenon , surface treatment methods, and so on. People with different cultural backgrounds and from different areas might have used different types of carpentry tools in past. However, carpentry tools in the countryside of South China gradually become unified and modernized due to the process of modernization over the past 40 years.

iii. Logging and transportation

Logging and transportation were dangerous and difficult tasks in pre-industrial society. Due to poor roads and a lack of large animals in the mountainous areas of South China in the past, the lengths of logs were usually restricted for transportation. Long logs cause much more difficulties than do short logs during the transportation process. Thus, the practicalities of transportation determined the length of building materials available in a wooden granary construction.

iv. Drying duration of wood

The drying duration of wooden components is related to the wood's future shrinkage performance when it is made into a wooden granary. This performance also has an effect on how carpenters deal with deformation in granary construction. To lessen the impact of shrinkage of wooden components, carpenters usually tried to dry wood for a longer period. In practice, however, the conventional drying duration of wood was decided by diverse factors, varying from place to place.

1.1.2 A brief introduction of South China

Generally, South China is referred to as a vast area south of the Qinling-Huaihe River boundary (Fig. 1.2) and east of the Qinghai-Tibet Plateau. Some scholars suggested that the demarcation line between North China and South China should actually be a zone named the " north–south" demarcation zone (张剑 , 2012, p. 32). Being separated by this demarcation zone, North China and South China mainly differ in terms of a series of climatic factors (temperature, rainfall, and humidity), geographical conditions (geomorphology and vegetation), and main crops.

1.1.2.1 Climate

Compared with North China, the main climatic characteristics of South China can be summarized by the terms: warmth and humidity. Monsoon season brings abundant precipitation in this region. Shown in map 1.3, the annual precipitation of most of the regions of South China is over 1,000 ml. In Southeast China, most of the rain happens in spring and summer seasons, while in Southwest China most of the rain falls in late summer and early autumn (刘明光 , 1998, p. 61). The annual average relative humidity value is over 70% in nearly all regions of South China (刘明光 , 1998, p. 64). Such climate conditions provide a climate highly suitable for plant growth.

1.1.2.2 Terrain

According to the terrain, South China could be divided into two parts: Southeast China and Southwest China (Fig. 1.4). Southeast China mainly consists of a series of hilly areas and fragmented plains below 500 m above sea level. The Wuyi mountain range is the main mountain range of Southeast China. It is located in the north of Fujian and isolates the Fujian area from the other hilly areas of Southeast China. On the other hand, Southwest China is mainly covered in steeper upland regions and mountains at an altitude of 1,000–2,000 meters above sea level; only the Sichuan Basin is lower than 500 meters above sea level. Apart from the Sichuan Basin, there are only scattered flatter hilly regions distributed along some rivers.

With more flat hilly areas and plains, Southeast China contains much better farming conditions than does Southwest China. It has been a major area for rice production for China as a whole since the Song dynasty (960–1279) (韩 茂 莉 , 2012, pp. 60-61). Han people possessed nearly all of fertile hilly areas and plains in this region. While in Southwest China the amount of arable land is much less.

Fig. 1.2 Provinces of South China

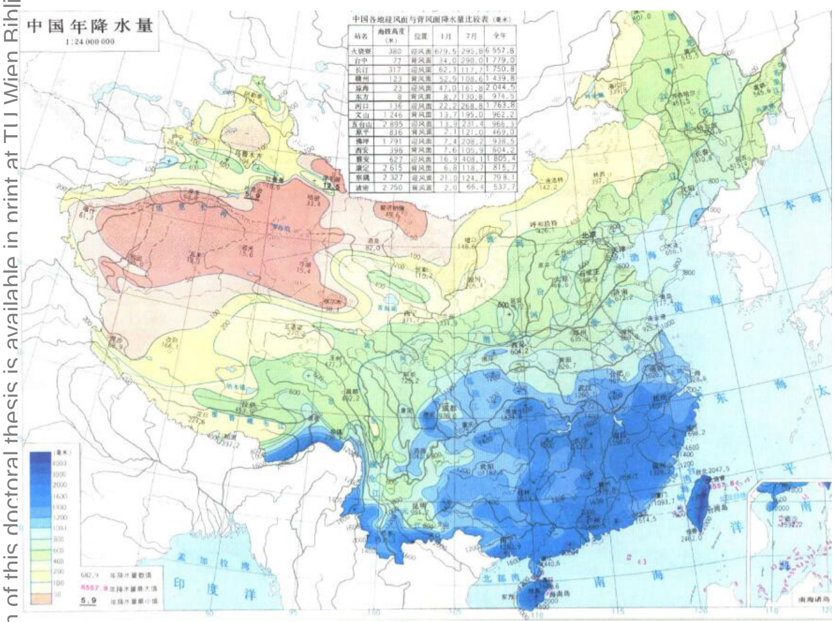


Fig. 1.3 Annual precipitation in China (source: 刘明光 , 1998, p. 60)

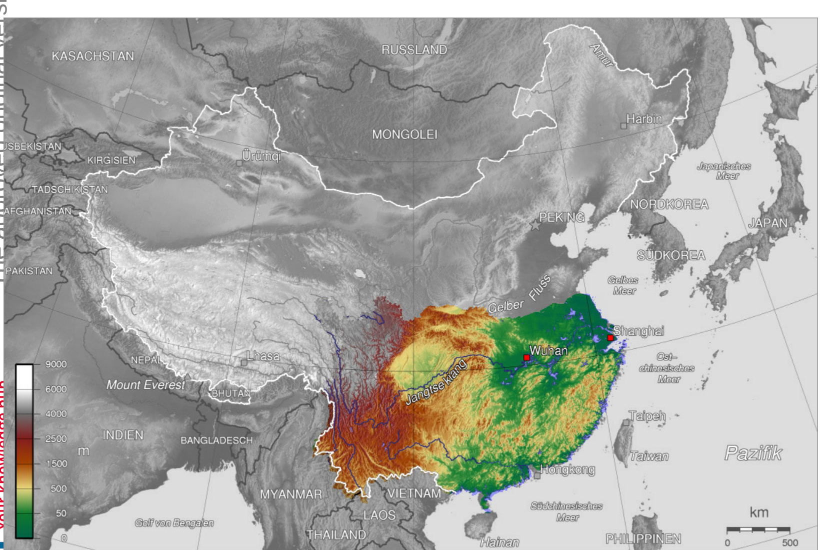


Fig. 1.4 The topographic map of South China (Based on a map via: https://www.weltkarte.com/asien/landkarten-china-weitere-karten-und-infos/landkarte-china-topographische-karte.htm)

The steeper slopes and poor soil conditions of most mountainous areas in Southwest China are unsuitable for ordinary water-rice growth. People need to make much more effort to cultivate rice in such environments. Diverse ethnic groups have settled these mountainous areas.

Four areas of South China have been selected for study in this dissertation: Mid-North Fujian, the Rgyal-rong region of Sichuan, Southeast Guizhou, and Southwest Yunnan. Among them, Mid-North Fujian is located in the Southeast Coastal Hilly Area of Southeast China; the Rgyal-rong region is located in the boundary area of Tibetan plateau and the Sichuan basin of Southwest China; Southeast Guizhou is located in the Yunnan-Guizhou Plateau; and Southwest Yunnan is located in Southern Tibetan plateau (周廷儒, 1956).

1.1.2.3 Agricultural planting

In the largest part of South China, rice is the traditional main staple crop . The yield of rice is higher than that of many other types of crops. According to the official statistical reports from 1911 to 1949, the yield per *Mu*[6] of rice fields was generally around 165 kg—more than twice that of wheat in the same area in nearly all of South China (许道夫, 1983, pp. 23-65). The yield of hybrid rice, widely promoted in the S outh since the late 1970s, is double that of normal rice.

6.*Mu*（亩）: An ancient unit of area that is often used in south Asia. 1 MU=666.66m^2.

In South China, two major varieties of rice are Indica rice (*Oryza sativa* subsp. *Indica*) and Japonica rice (*O. sativa* subsp. *Japonica*). In the following, these two varieties are collectively referred to as normal rice, in contrast to sticky rice and upland rice. Since the cultivation of rice generally requires a humid and warm environment, local farmers usually need to build flooded fields to plant water rice. Farmers had to erect a series of the artificial drain systems for this purpose.

Due to the continually increasing population of South China since the Tang dynasty (628–907), the per capita arable land area was correspondingly decreasing (韩茂莉, 2012, p. 42). In the Qing dynasty (1616–1912), for example, the per capita arable land of whole China was 1–3 *Mu*, while the per capita arable land of the Tang dynasty was around 26 *Mu* (ibid.). Thus, Han farmers who had lived in Southeastern China increasingly immigrated into Southwest China in search of more arable lands in the hilly areas and basins of Southwest China (韩茂莉, 2012, p. 68). Consequently this migration pressure forced some aboriginal peoples of this area to give way and to move westward or southward into remote mountainous areas, where arable land is less common.

In these remote mountainous areas, plain areas were fragmentary. Apart from these small amounts of plain areas, the steep slopes are usually unsuitable for planting normal rice. Thus, farmers needed to plant other crops. To adapt to the local environmental conditions, they developed a variety of farming methods in different areas. In the mountainous areas of Southwest Yunnan, some ethnic groups, such as the Wa[7] people or the Pulang[8] people , used to plant upland rice

on the steep and less fertile slopes through a slash and burn method. The average yield per *Mu* of the upland rice was 85 kg in 1949 (蔡 鹏 顺 , 1997, p. 165). In the mountainous areas of South Guizhou, by contrast, the low temperature and the lack of sunshine made it hard to plant normal rice. Thus, local farmers cultivated sticky rice, which can grow at a lower temperature and with less sunshine, in terraced fields (罗 康 智 , 2012, pp. 110,112). The yield per *Mu* of the upland rice was generally somewhat less than that of normal rice (许 道 夫 , 1983, p. 62). In the Rgyal-rong region of the Tibetan plateau, the adverse environmental conditions of the high attitudinal region were unsuitable for most of the crops, although highland barley grows well. The yield per *Mu* of the highland barley was around 80 kg in Aba in 1949 (阿坝藏族羌族自治州地方志编纂委员会 , 1994, p. 309).

Starting from the Ming dynasty, three species of imported crops, namely potato, sweet potato, maize, were widely planted in the mountainous areas of South China (韩茂莉 , 2012, p. 192). These crops are a kind of drought tolerant and can grow in poorer soil than can normal rice. Additionally, potatoes can even germinate at quite a low temperature, such as 5–8°C . These features enable them to grow well on the steep and less fertile mountainous slopes where rice and wheat cannot grow. However, either Han Chinese or other ethnic groups are more accustomed to cooking and eating cereal grains, such as rice or highland barley. Thus potato, sweet potato, and maize are generally treated as animal feeds, emergency foods, or side dishes in addition to rice. Only very poor mountainous villages would accept them as staple foods.

1.1.2.4 Forest resources

According to the Chinese forest cover map (Fig. 1.5), the forest coverage area of South China was much larger than that of North China in 2000. The major forestry areas of South China are subtropical broadleaf evergreen forests. While there are some tropical monsoon rain forest and rain forest regions along the southernmost border (Fig. 1.6). Carpenters usually choose one or several specific types of trees in the local forests for their construction works.

7. Wa people (佤 族): The Wa people are an ethnic group that lives mainly in northern Myanmar, in the northern part of Shan State and the eastern part of Kachin State, near and along Burma's border with China, as well as in Yunnan, China. The Wa language forms a language group belonging to the Palaungic branch of the Austroasiatic language family. It formerly had no script and the few Wa that were literate used Chinese characters, while others used the Shan language and its script. Christian missionary work among the Wa began at the beginning of the 20th century first in the Burmese and later in the Chinese areas of the Wa territory.

8. Pulang people (布 朗 族): Pulang (also spelled Bulang) people are an ethnic group mostly lives in Yunnan of China. The Blang language belongs to the Palaungic branch of

Fig. 1.5

Fig. 1.6

Fig. 1.5 Chinese forest cover map (source:World Resources Institute,2016)

Fig. 1.6 Vegetation zones Map of China (Based on the map 'Vegetation zones Map of China,Hou Xueyi ',1979)

The species of local construction timber can differ from one place to another. Southeast Guizhou and Mid-North Fujian generally use Chinese fir (*Cunninghamia lanceolata*) in construction projects. They also use pine trees in some cases. Spruce and pine trees are two major types of construction timber in Rgyal-rong area of Sichuan. In contrast, Wa and Pulang villages of Southwest Yunnan mostly use different kinds of hardwoods in their buildings. Generally, the traditional construction timbers of areas with subtropical broadleaf evergreen forest are mostly softwoods. Hardwoods are widely used as building materials in areas covered with tropical monsoon rain forests or with tropical rain forests.

Apart from trees, bamboo is also a common material used in building construction. Bamboo is distributed widely in South China, except in certain high-altitude areas, such as the Rgyal-rong area of Sichuan. It grows fast and is easy to obtain, but it is not as strong or durable as normal wood. Thus, it was mostly used to build short-term buildings or made into non-structural components of buildings.

1.1.2.5 Cultural diversity and different building technologies

In contrast to North China, which boasts vast plains, South China has vast mountainous areas. It consisted of several partly self-governed regions for much of history. In the early Han dynasty (202–220 BC), most mountainous areas of the current South China remained occupied by a series of small kingdoms and tribes, such as Qiang（羌，nowadays Tibetan area of Sichuan), Dian Kingdom（滇，nowadays Yunnan), Ming Yue Kingdom（闽越，nowadays Fujian), Nanyue（南越，nowadays Guangxi and Guangdong), and Yelang（夜郎，nowadays Guizhou). The culture and societies of these kingdoms and tribes differed considerably from those of the Han Empire. Gradually, in the following years, these regions surrendered to the central government. However, many of these regions maintained their self-governed conditions for more than two thousand. Until the Ming dynasty, many mountainous regions of Southwestern China were still ruled by the headmen of different local tribes[9].

9. Since Yuan dynasty, central government realized the difficulty of governing these remote mountainous regions. They recognized headmen of local ethnic groups as the imperial officials, and admitted their ruling in certain ethnic regions. On the other hand, these headmen should pay tax to the central governments.

As a result, a variety of ethnic groups belonging to different linguistic groups continue to inhabit various areas of South China, as shown in map 1.7. Difficult travel conditions and language barriers made some mountainous areas more easily isolated, having regional building traditions developed according to different local environmental and societal factors.

In South China, two major types of traditional wooden building technologies exist: log-construction building technology and skeleton- structure building technology. Log-construction building technology is mostly used in the forest zones of the Tibetan region. It is considered to be a primitive building technology that can be finished by simple tools. Apart from the Tibetan region, people of other regions have traditionally used skeleton wooden structures to build their houses. Among the several variants of skeleton structures, a common type is *Chuandou*（穿斗）, widely used in the rural buildings of the Han and Dong villages in South China. “In a *Chuandou* type, a transverse framework is formed by tie-beams and sills tying into columns. It is called ‘ *San*（ 扇 ）’ or ‘ *Sanjia*（扇架 ）’ in Chinese, and can be seen as a basic unit of the framework. Each purlin is supported by a column. Two parallel transverse frameworks are connected by longitudinal purlins and sills, which form a rectangular space called a bay” (Guo, 1999, p. 54). However, in Southwestern Yunnan, Pulang, and Wa people have traditionally developed another type of skeleton wooden building technology, differing from *Chuandou* in terms of structural connections and

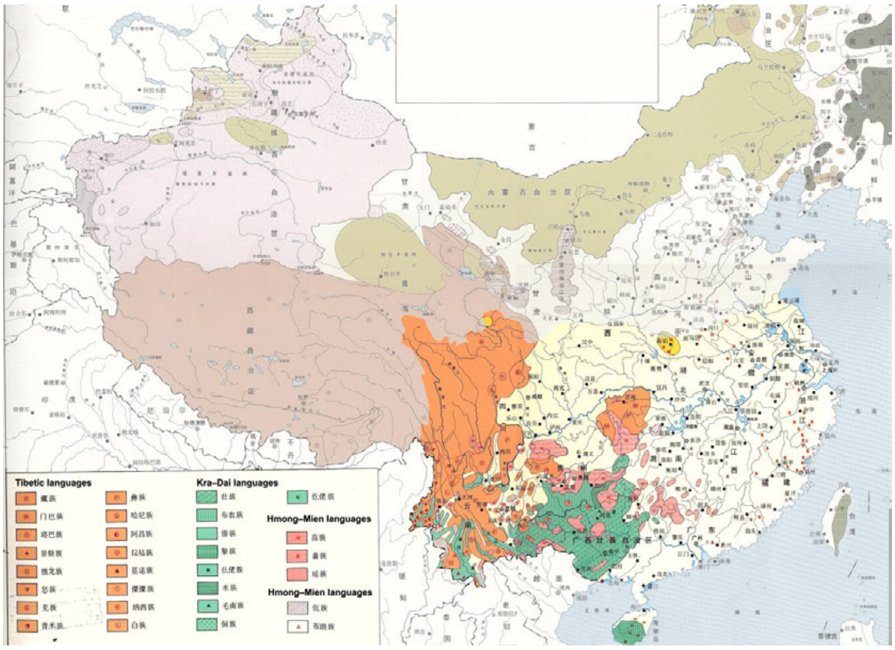


Fig. 1.7 Ethnic Linguistic groups distribution in South China (Based on the map 'National minorities in China'， Language Atlas of China， 1987)

construction method.

1.1.3 Wooden granaries in Chinese farm families' daily lives

In South China, the majority of remaining wooden granaries are private properties belonging to farm families. They have strong relationship with their owners' daily lives.

1.1.3.1 Diverse food storage methods in a farm family

In the pre-industrial period, most of the families in the countryside of South China were self-sufficient units. They relied on cultivating their rice fields to produce enough food to support their whole family. Many of them also did animal husbandry or forestry as well. In some areas that lacked arable lands such as Fujian, many people plant more tea or tobacco than rice, using tea or tobacco to exchange enough rice for consumption.

Nearly all rural families of South China have cereals as their staple. Most of the regions eat rice, including normal rice, sticky rice, and highland rice. Tibetan areas have highland barley. Due to the shortage of arable land in South China, farmers of hilly areas and mountainous areas generally plant maize, potato, or sweet potato on the slopes for food supply and animal feed. Some farmers of plains areas carry on rotational cultivation to gain more output from their rice fields. However, the total output of these fields is usually less than twice the yield of single-season rice.

Different harvests should be stored in different ways according to their different natures. Cereals generally need a dark, dry and cold place. Maize needs to be stored in dry and ventilated space, and potatoes should be stored in dark and cold places. For preserving cereals, people usually build fine, sealed, and strong structures. Maize and potatoes are usually kept in a more rough way, such as hanging on the open-air place (Fig. 1.8).

An ordinary farmer family is inclined to store hulled cereal grains and cereal grains with husks in different ways. People usually believed that cereal grains with husks can be preserved longer than can hulled grains. Thus, most cereals harvested are stored before being hulled. However, cereal grains should be hulled before being cooked (Fig. 1.9). In past, some ethnic groups, such as the Dulong (独龙) people, did the husking every morning. Most of the farmers traditionally do this work very few days. These hulled cereal grains are generally stored in clay pots or small wooden cabinets located in places close to kitchens or in kitchens (Fig. 1.10). They comprise stored grain for the families to consume in a few days. Most cereals

Fig. 1.8 Maizes stored under roof eaves, Chenchun, Yunnan

Fig. 1.10 An open-fireplace kitchen of Yao People, Dongmeng, Guizhou

Fig. 1.9 Stone-bamboo rice huller in Genzhi Tu of Yuan Dynasty (source: Arthur M. Sackler Gallery)

would be put into separate and specified storage places: granaries. These buildings were mostly located in places far from sources of fire. Such storage separation was already shown in some Neolithic settlements of South China, such as Pengtou Shan site (9000 – 5500 BC).

Furthermore, people generally store the same species of cereal grains harvested in different periods in different containers. Usually they would add divisions inside granaries.

1.1.3.2 Size of a wooden granary

A granary is a must in traditional agriculture activities. It is usually seen as the treasury of a farmers' family. In some regions, it might not only preserve cereal grains, but also some precious foods such as honey or dry meats.

In many places, each farmers' family has their own independent granaries. According to the tradition of Yao and Wa people, the establishment of a new nuclear family is usually accompanied by the construction of a new house and a new granary. On the other hand, there are villages that lack space for additional building sites. Their inhabitant are inclined to live in an extended- family mode: some nuclear families with blood relationships live under the same house. This communal living arrangement is common in the Han and Dong peoples. Some of these extend-families also share a large granary together. However, such granaries usually consist of several storage components. Each nuclear family would still use their own independent storeroom in this type of granary.

Ideally, the amount of stored food in a farm family's granary generally relates to the size of this family. It can differ from one area to another due to the different modes of family organization in different regions. In order to prevent food shortage, the amount of stored food should feed a family for one year. In some cases, stored food should be also prepared for the consumption by livestock. Secondly, the amount of stored food for one farmer's family was also related to the trade network. According to my investigation, families who settled down in remote mountainous areas were inclined to store more food than rural families living in plain areas. Due to the difficult traffic conditions, importing food into remote mountainous areas is costly. In order to prevent unpredictable natural disasters leading to crop failures the next year, farmers of remote mountainous areas usually paid more attention to preparing adequate food reserves. They generally stored food in an amount more than would be required by one family over a year.

1.2 Questions and objectives

1.2.1 Questions

In this dissertation, four mountainous areas that preserve a number of traditional wooden granaries in South China were chosen for further examination: Southern Yunnan province, Mid-Northern Fujian province, Southeastern Guizhou province, and Western Sichuan (Fig. 1.11). The geographical conditions, climate, and vegetation of these regions varies. In addition, most inhabitants of these regions belong to different ethnic groups using different languages. Language is one very obvious cultural characteristic. Maintenance and cultivation of a langue expenses expresses affinity to a different cultural background usually caused by immigration. This consideration explains immediately why we must expect different building traditions in the four mentioned regions.

According to my investigation, wooden granaries of various forms existed in these areas. In one region or even one village, several different types of wooden granaries would exist. I have addressed three major questions on wooden granaries and the building craft of these regions:

- **Why do wooden granaries differ in form?**
- **What factors determine the building technology?**
- **Which factors promoted changes in building technologies?**

1.2.2 Objectives

To answer the above questions, the research is carried out in two different parts: historical study and case studies.

The historical study offers a comprehensive overview of Chinese granaries built with various types of materials, from ancient times to the present. Mainly based on a series of historical records and archaeological reports, this study mainly aims to trace the distribution ranges, applications, and changes of wooden granaries in Chinese history, analysing the relationships between environmental factors, social factors, and the forms of wooden granaries, as well as considering the developmental history of the building technology of wooden granaries.

In respect to selected case studies, I carried out several field trips in South China from 2013 to 2016, aiming to find and collect first-hand information about the most interesting wooden granaries in South China. Ten villages were then selected for further study, focusing on

Fig. 1.11 Research areas in South China

their characteristic granaries. In order to do a comprehensive study on the selected wooden granaries, this research covers the following three levels: selected granaries, the villages where these granaries are located, and the regions in which these villages are located.

i. Selected granaries

I started with a typological study of all granaries in a village in order to decide afterwards which granaries will be selected for further detailed research. Depending on the result of the preliminary study one, two or more granaries were selected according to the criterion of being locally significance. I thus had no predetermined number of research objects.

A series of detailed measurement works on the selected granaries and interviews with the locals were carried out in order to obtain first-hand information of these granaries. The measurement work of each selected granary mostly consists of plans, sections, structural analyses, and joint details. The interviews with the owners of these granaries and local carpenters were mainly focused on the terms of use and the building technology. Some of the literature adds knowledge of local building technology and offers a chance to compare previous observation with my own research and with local's perceptions and oral explanations. Singular typical granaries were selected, despite their poor conditions. Studies on missing and damaged parts of these granaries were carried out to allow reconstruction drawings. I decided to depict all selected granaries in isometric drawings in order to communicate this information as clear as possible.

ii. Selected villages

Information about the selected villages was collected from literature reviews and interviews with locals. In order to study the relationship between granaries and their contexts, for each selected village the following information were collected: the village's scale, population, climate, topography, layout, and economic factors. In addition, the distribution of the granaries and the relationship between dwelling and related granary was also studied.

iii. Selected region

In the same geographical region, many villages share similar environmental, economic, forestry, and agricultural features. Even building technologies of different villages and different ethnic groups within one region will show some similarities. The four selected mountainous regions mentioned before prove this statement. Thus, in order to provide wider relative background factors relating to the building technologies of wooden granaries in one region, a brief introduction of the selected mountainous regions is offered before entering the specific village. The following aspects of these regions are described and analysed: geographical environment, cultural and social background, main staples and their harvest methods, forestry and building traditions.

1.3 Research state on Chinese granary

Few studies have been published on traditional granaries in China and their building technology. Most scholars who study vernacular architecture are more interested in dwellings. Additionally, as the number of traditional granaries has decreased sharply over the past 40 years, it has already become difficult to see them in many villages. Knowledge relevant to wooden granaries of South China mostly derives from the following three sources: vernacular architecture studies and records; anthropological reports and social survey reports; and historical studies. Aside from these, county annals and government reports also provide us with some information about granaries.

1.3.1 Vernacular architecture studies concerning the existing wooden granaries in South China

Due to the superior building craft of Dong carpenters, more studies have been published concerning the wooden granaries in Dong areas compared with those of other ethnic groups' areas. Shigeo Asakawa, a Japanese architectural scholar, divided the Dong granaries into three categories according to the forms of their roof structures. He provided measurement drawings about the typological classification belonging to different categories in Dong villages (ASAKAWA, 1994). Chen Congzhou published some measurement drawings about two other granaries and one drying house of the same area in 1997 without any textual description (陈从周, 1997). Granaries shown in these studies are all small granaries. Large granaries with drying racks were firstly studied by Klaus Zwerger. He classified these special Dong granaries into a category, An Baukörper angehängte Getreideharfe , and provided a series of high-quality measurement drawings. In his research, he explained the relationship between the functional requirement of granaries and the development of the characteristics of these granaries (Zwerger, 2011). Later, Xin Jing carried out a study on the Dong granaries of the southern Dong area. The study tries to explain the relationship between building technology and related factors. In addition she illustrates the building processes of a simple granary. However, her research is focused only on the simplest granaries in Dong villages, and the building processes shown in her work demonstrate those simplified objects that were developed after the 1980s (辛静 , 2014).

Anthropologist Zhao Qiaoyan carried out research on the storage rooms of a Dong village located in Guangxi province. Her study was dedicated to interpreting the cultural meaning of the granary and tried to connect the location of the granary in a dwelling according to its religious interpretations. As an anthropological study, however, it lacks scientific measurement drawings (赵巧艳 , 2014).

Far fewer studies have been done on Han Chinese granaries than on Dong granaries. Kuang Lichun has studied storage methods among the Han villages of Hunan province. Her findings are that most of the Han families use wooden cabinets instead of their former separate buildings after the 1970s. The reason is the sharp decline in per capita possession of cultivated land （ 匡 丽 春 , 2011). According to a series of governmental statistics reports in 2004–2006, it is evident that most of the Han farmers used storage methods accepting new materials to replace their traditional granaries (王若兰 , 2006, p. 50; 朱邦雄 , 2006, p. 38).This could explain why records related to Han Chinese granaries are few. The two case studies from the mid-Fujian areas in this dissertation have not been previously recorded in any other academic work. The other case study introducing a village in Eastern Fujian, actually focuses on a type of Han Chinese dwelling combined with the granary. This type of dwelling was studied and recorded by Li Qianlang and Chen Zhihua separately (陈 志 华 , 2007) (李 乾 朗 , 2009). Both realized the direct relationship between the local climate, social arrangement, and the special building forms of the dwellings. However, the quality of their drawings is insufficient. The investigation about the building technology of dwellings is also absent in their studies.

Similar to the Han granaries of Eastern Fujian the wooden log construction granaries of Rgyalrong Tibetan region were mostly located in their tower dwellings. Ryser has described and drawn detailed illustrations of log-construction granaries in his study of the Tibetans of Sichuan (Ryser, 1997). Zhang Yan provides further measurement drawings of dwellings in Sha'er area of Rgyalrong Tibetan region (张 燕 , 2012). They all point out the connection between the spatial planning of the dwelling and the harvest process. Their studies lack analysis of the building technology of the log construction in the dwelling, and consideration of the entire building process for the dwelling is also absent. Wang Jihong analysed the structural function of the log construction in the whole dwelling, but without offering any detailed measurements (王 及 宏 , 2011). Several scholars have contributed information about the building technology of the local tower dwellings (保罗 , 1996) (陈颖, 刘长存 , 2003) (毛良河 , 2005), but most of these researches have been focused on masonry building technology and ignore the wooden building technology of the tower dwellings.

Few academic works have dealt with the granaries of the Wa, the Pulang, and the Yao of South China. Anthropological research on a Pulang village provides valuable information about historical change, building materials, and the building process of the Pulang granary (街顺宝, 2009). Some researchers have investigated the layout of some Pulang and Wa villages and have noticed that the location of granaries was mostly far away from the dwellings (王翠兰, 1993). Aside from these, only some studies about vernacular architecture have provided photos of the granaries of the Wa, the Pulang, and the Yao villages, demonstrating examples of primitive buildings (熊伟, 2012).

1.3.2 Building technology

Some architectural researchers have contributed knowledge of the wooden building traditions of one specific area or one specific ethnic group when investigating vernacular architecture, such as Cai Ling, Mao Lianghe and others. However, for wooden granaries, this information is insufficient. First, most of this knowledge is related to dwelling constructions that differ from granary constructions. Secondly, the majority of the building technologies recorded in these vernacular architecture studies represent the building technologies of the past 20 years. Due to import of the modern carpentry tools such as the circular saw in the 1960–70s, the wooden building technologies of many villages of South China changed accordingly. However, the wooden-granary study cases in my dissertation were built mostly before the 1970s. In order to better understand these traditional wooden granaries, understanding of Chinese building technology before the 1970s is critical. Thirdly, some important building techniques have been mostly ignored in the studies of traditional construction processes, such as logging and foundation construction. These preparation works offer meaningful information to better understand the building technology of the wooden granary, however.

Some anthropological and sociological reports provide necessary and detailed information, such as the traditional foundation-building techniques of Dong people (赵巧艳, 2014) and the logging traditions of Dong people (刘江荣, 2015). The building order of the wooden drying racks of tower dwellings of Rgyalrong Tibetan region is recorded as an example sentence in a dictionary (向柏霖, 2016). Some county annals provide important information about the forestry, traditional logging methods, and photographs of carpentry tools, keeping alive an imagination of components relevant for building granaries, although these tools have become extinct (福建省地方志编纂委员会, 1993; 福建省三明市地方志编纂委员会, 2002) (李明富, 1998).

Old photo albums might also contribute to improving our understanding of building technologies of different wooden granaries. Photos taken by Zhuang Xueben in 1934–1942 show the earth ramming process and lime production in Rgyalrong Tibetan region（庄学本，2009）. Xu Zhiyuan visited the Wa area of Yunnan in 1956–1957 and took a series of photographs about logging, wood transportation, and roofing work（徐志远，2009）.

My own work on the building technology includes interviews with experienced local carpenters and architectural archaeology research on remaining granaries.

1.3.3 Historical study of granary

Most of the case studies in my dissertation target rural granaries built between the late-19th century and the mid-20th century. Some large state granaries were built even earlier, such as Ganzhou granary, which was built in the Ming–Qing dynasty. However, historical granaries built before the Ming dynasty (1368–1644) have not yet been found to be preserved above ground. In order to obtain the information about the granaries built before the Ming dynasty, researchers have mostly relied upon archaeological excavations, historical models, paintings, and literary works.

Archaeological reports about the settlements and the remains of granaries are the main sources of our knowledge of historical granaries. Based on a series of archaeological excavations, archaeologist Yu Fuwei published a general overview of the historical development of underground granaries from the Neolithic period (ca. 6200 BC–1600 BC) to the Tang dynasty (618–907)（余扶危，1982）. Subsequently, another archaeologist involved the above-ground granaries into his research field and provides another brief introduction about the historical granaries from the Neolithic period (ca. 6200–1600 BC) to the Han dynasty (202 BC–220 AD)（杜葆仁，1984）. Then, some later researchers began to focus on the historical granaries of one specific period or dynasty and provided deeper studies. Wang carried on a series of studies on the storage method during Neolithic period and tried to reveal the relationship between the development of agricultural technology and the development of the building technique for the granary（余黎星，2012；王秋玲，2011；王秋玲，2011）.

Nearly all of the archaeological excavation works of granaries were executed around underground granaries and large above-ground granaries. The remains of large above-ground granaries were proven to belong to the state granaries of certain dynasties, such as the *Hanjia* granary of the Tang dynasty, the *Baiwandan* granary of the Han dynasty, Suangjing granary of the Song dynasty, and so on（王

书敏，2011; 田亚岐，2005; 张婷瑜，2017). However, the archaeological remains of the above-ground private granaries are quite rare, mostly due to their small scales and building materials, which made it hard to find any valuable historical evidence. Researchers had to look for clues from building models and paintings to depict the historical forms of the private granaries built before the 19th century.

Pottery granaries were one type of the most common funerary objects used in the Han dynasty. According to their original function, it is believed that most of their references should be to real private granaries of that period. Many researchers, such as Guo Qinghua, Li Guige, and Zhang Wei, contributed separately comprehensive studies on granary models and did classification works in different ways (张玮，2012; 李桂阁，2005; Guo, 2010). Li Guige has pointed out the different features presented in the granary models of North China and South China. She has also suggested that the building technology for granaries differed between North and South China during the Han dynasty (李桂阁，2005). Guo Qinghua, as an architectural historian, focused more on studying the building technology shown in these models (Guo, 2010).

Granaries became a motif of painting since the Han dynasty (202 BC–220 AD). These paintings could also offer some useful information about the appearances of the granaries of that period.

In addition, some specialized laws and regulations of some dynasties are related to the management and construction of the state granary. They reflect the forms and the building technology of state granaries at their times. These laws and regulations include *Canglv* (Granary Law, 仓律) of the Qin dynasty(221-206 BC), *Cangkuling* (Granary Law, 唐仓库令) of *Tang Code* in the Tang dynasty (618–907), *Cangkuling* (Granary Law, 宋仓库令) of *Song Code* in the Song dynasty (960-1279), *Gongbu Cangku Xuzhi* (Necessary Construction Manual of Official Buildings, 明工部厂库须知) of the Ming dynasty(1368–1644), and *Gongbu Gongchen Zhuofa Zheli* (Construction Principles, 清工部做法则例) of the Qing dynasty(1644-1912). In addition, historical official proposals for granary construction can also provide references for the building forms and building technology of granaries in that period, such as *Cang'ao Yi* (Suggestion about granaries, 仓廒议) from a Ming governmental official, Zhang Chaorui(张朝瑞).

Meanwhile as the granary is one of the key parts of the harvest, some historical agriculture books have also recorded suggestions for building granaries in ancient China, for instance, *Nongshu* (Agriculture Book, 农书)[10] of the Yuan dynasty, *Qingding Shoushi Tongkao* (钦定授时通考) of the Qing dynasty. This information also contributes to improving our understanding of the building technology used to construct historical granaries.

10.*Nongshu* (农书) is an encyclopedia of agriculture of Yuan Dynasty, writtern by Wangzhen (王祯,1271-1368).

11.*Qingding Shoushi Tongkao* (钦定授时通考), an agriculture book edited in Qing dynasty according to the emperor Qinglong's order. It was seen as a Construction manual book.

2. History of Granary in China

In this chapter, I extend the historical survey to the whole of China. In Chinese history, underground pits and above-ground granaries represent the two major types of granaries used in China. Many studies have suggested that pits were mostly used in North China, while above-ground granaries were largely built in South China. This difference was caused by the variance in climate and geographical factors between these two regions. However, the division was not generally so strict. Some historical resources describe that pits were used in some settlements of South China in the Neolithic period, and above-ground granaries were the main form of state granaries in North China during the Ming–Qing dynasty.

Comprehensive research on the history of granary in the whole of China is necessary to understand what caused the changes in the forms and appearances of granaries. Social change seems to have had specific transformational power. Additionally such research can provide certain information about the development of the building technology of wooden granaries in China.

2.1 The Neolithic period (ca. 6200–1600 BC)

The erection of granaries is to be assumed to have started after humans had settled into fixed habitation and carried out regular agricultural activities. In China, this shift to agrarian culture happened in Neolithic period. A large number of granaries' remains and some other concerning remains have been uncovered in many Neolithic settlements in China. Scholars had already done much work to reconstruct the original forms of those granaries.

2.1.1 Pit

The remains of grain storage pits with carbonized grain were found in Neolithic settlements in both North China and in South China. The grain storage pit was suggested to be the earliest form of granaries in North China, and it is still used in many places of today's North China. Archaeologists have concluded that this method of storage might have been adopted for the following reasons: 1) lack of other building technology, 2) safety requirements, and 3) provision of an effective storage environment for the grain through constant temperature and enclosure (余扶危, 1982, pp. 136,137).

1.Keshengzhuang sites (客省庄遗址), is a late Neolithic remain located in middle Yellow river valley of northern China from about 3000 to 1900 BC. It is generally classified as part of Longshan culture.

2. Houma Qiaoshandi (侯马乔山底): is a Neolithic site found in Lingfen, Shangxi, North China.

3. Beishouling (北首岭) is a Neolithic site found in Baoji, Shanxi, North China. It belongs to Yanshao Culture.

4. Hemudu sites(河姆渡遗址) is a Neolithic site found in Ningbo, Zhejiang, South China. The Hemudu culture lasted from ca. 5500 to ca. 3300 BC.

5. Xiantan Miao site (仙 坛 庙 遗 址) is a Neolithic site found in Haiyan, Zhejiang, South China. It can be dated from ca. 4000-ca. 3300 BC, and belongs to Songzhe culture.

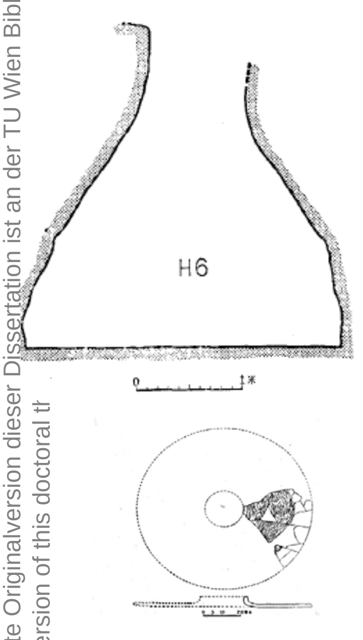


Fig 2.1 Storage pit and remains of a clay lid in Keshengzhuang site.(source: 中国科学院考古研究所 ,1962,p47; p69)

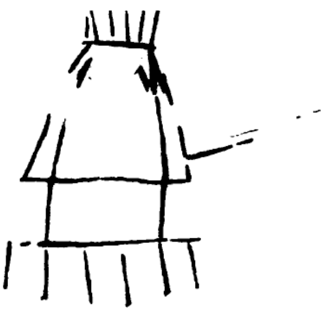


Fig 2.2 A house image found on a clay plate in Xiantan Miao site. (source: 王依依 , 2005, p97)

The grain storage pits of this period generally were not large. The image in Fig. 2.1 shows a typical example from the Keshengzhuang site(客省庄遗址)[1], Shanxi province. With a depth of 2.5 meters, this storage remain presents one of the common patterns of pits of the late Neolithic period: a small opening and a large bottom. The opening diameter was around 1 m. The inner earth surface of the pit was flattened by being rammed. This method is a primitive form of waterproofing. Broken round pottery pieces were also found inside this pit. They are supposed to be the original lid of the pit, used to protect the stored grain from rain (中国科学院考古研究所 , 1962, p. 47).

In order to prevent underground moisture from penetrating into the pit, different types of inner surface treatments had been developed for use inside the pits since the mid-Neolithic periods: One prominent treatment method was to bake the inner earth surface of the pit . A second example of such a treatment method was found in Houma Qiaoshandi (侯马乔山底)[2], North China (余黎星 , 2012, p. 81): Daubing a layer of mud and straw on the inner surface of the pits. Such examples are also found in pits from the Beishouling(北首岭)[3]remain in North China (王建华 , 2012, p. 61).

2.1.2 Above-ground granary

Compared with pits of the time, the above-ground granaries of the Neolithic period have not been widely represented in the archaeological findings. Up to now all archaeological findings related to above-ground granaries have been located in South China.

Wooden granaries were supposed to be built in the Hemudu site (河姆渡遗址)[4]of South China during the Neolithic period. In the Hemudu site, stacks of carbonized rice remains were found in a mass of remains of wooden architectural elements (王秋玲 , 2011, p. 80). These remains were seen as an evidence of the use of wooden granaries in Hemudu during the Neolithic period. Further evidence came from the Xiantan Miao site (仙坛庙遗址)[5], which was also in South China. A clay plate carved with an image of a small building was found in this site. The building shown in the image is supported by several posts (Fig. 2.2). Archaeological studies have suggested that ordinary dwellings of this site were all built on the ground. Thus, scholars believe that the building image on the plate is not that of an ordinary dwelling. Wang Yiyi has suggested that this building image represents a primitive granary, owing to the significant feature of the elevated floor (王依依 , 2005, p. 98). Using posts to the elevate floor of a granary is a most simple way to keep the stored grain away from the humid ground and promote air ventilation beneath the floor of the granary, thus to carry away the moisture and heat produced by the stored grain. Moreover, such a design can prevent animals from approaching the stored grain, if the floor is elevated high enough. This feature can be seen in the *Ganlan* （ 干 栏 ）[6] granary models of the Han dynasty and many wooden granaries of current South China.

2.1.3 Different storage methods in farm families

In addition to the two major types of granaries mentioned above, clay pots were also widely used for storing grain in Neolithic period (王 秋 玲 , 2011, p. 80). In the earliest permanently settled village of ancient China, the Pentoushan site (彭 头 山) [7], carbonized rice husks were found in pottery shard (王秋玲 , 2011, p. 76). These husks have been suggested as evidence of the application of clay pots in grain storage during this period. However, underground pits with carbonized rice were found in the same settlement remains. The archaeologist Wang Qiuling believes that the capacities of this primitive pottery was smaller than the capacity of storage pits. Thus, she concludes , in this primitive settlement, grain storage pottery was used to store grain for the short term, while storage pits were used to store grain over longer periods (王秋玲 , 2011, p. 77). Similar situations were found among the remains of other Neolithic settlements, such as the Banpo site (半坡遗址) [8](王建华 , 2012, p. 61).

Today, many farm families continue to use clay jars for short-term grain storage, putting them inside their kitchens, while the majority of their harvest would generally be stored in separate granaries. It is suggested that this kind of separation was originally due to the contradiction between the accessibility and fire-safety of the stored grain.

2.1.4 The origin of public granary and private granary

Chinese archaeologists believe that the land ownership in most of Neolithic villages and harvests from the owner's land belonged to the whole community (王秋玲 , 2011, p. 77). Thus, they state that the granaries of a Neolithic village should be assumed to have been mostly public granaries. As shown in many archaeological reports, grain storage pits were usually gathered in one or several certain areas close to the residential area in one settlement in the Neolithic period, such as Fufeng Anban site (扶 风 案 板 遗 址) [9] and Dahechun site (大河村遗址) [10](余黎星 , 2012, p. 80; 王建华 , 2012, p. 62). Many Chinese scholars believed such layouts also implied that the storage pits of this period were mostly public granaries (余 扶 危 , 1982, p. 140). However, starting from the middle of the Neolithic period, some grain storage pits were found inside the remains of dwellings, as shown in Qin'an Dadiwan (秦 安 大 地 湾) [11] (Fig. 2.3). They were assumed to be the primitive private granaries of families (王建华 , 2012, p. 62). This discovery was seen as important evidence of the origin of private property in the mid-Neolithic period of early Chinese history.

6. *Ganlan* (干栏): Buildings supported by posts, with a raised floor. It can be called as stilt house.

7. Pentoushan site (彭 头 山 遗 址) was discovered in Li County, Hunan, South China. It can be dated from 9000 BC to 5500 BC. The site is the earliest permanently settled village yet discovered in China (Higham, 1996, p. 63).

8. Banpo Site (半坡遗址) is a Neolithic site found in Shanxi, North China. It can be dated from ca. 6700- ca. 5600 BC, and belongs to Yangshao culture.

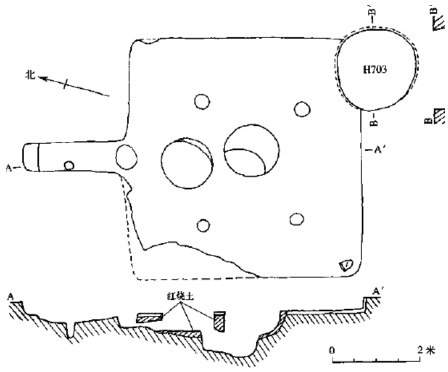


Fig 2.3 A grain pit was found in the eastern corner of the dwelling site, Qin'an Dadiwan. (source: 甘肃省文物考古研究所，2006,fig.204)

9. Fufen Anban Site (扶 风 案 板 遗 址) is an archaeological remain consisting settlements of Neolithic, Zhou dynasty and Han dynasty. It is located in Shanxi, North China.

10. Dahechun Site (大 河 村 遗 址) is a mid-Neolithic site found in Zhenzhou,Henan, North China.

11. Qin'an Dadiwan (秦 安 大 地 湾) is a Neolithic sites found in Qin'an, Ganshu, North China.

2.2 The Shang dynasty (ca. 1600–1046 BC)

The Shang dynasty is the earliest dynasty in traditional Chinese history supported by archaeological evidence. The ruled area of the Shang Kingdom was established along the banks of the lower Yellow River in Northern China. The Chinese Bronze Age had also begun in this region in around 1700 BC. During the Shan dynasty, state granaries emerged.

2.2.1 Brief introduction about state granaries

Accompanied by the establishment of the kingdom, state granaries began to be built in the Shang dynasty. In this dissertation, state granary refers to a granary built and managed by the government or the imperial administration. grains in state granaries was collected as tax. These stored grains in state granaries were the cornerstone of running the whole kingdom. Generally, there were three major functions of state granaries: paying salaries of government officials, supporting military actions, and disaster relief.

Due to the importance of state granaries and requirement for large capacity, state granaries usually showed the following features distinguished from ordinary granaries:

i.Large volume. The requirement of large capacity generally led to massive forms of state granaries. However, building a series of unified buildings or pits to form a granary complex was also common in Chinese history. Starting from Ming dynasty, due to a special granary policy, the scale of each granary as a unit of a state granary complex became similar to ordinary houses. Nevertheless, they were still larger than most private granaries.

ii.Defensive. Since the big amount of stored grain was the key factor of victory in a war, to prevent the stored grain from robbery or burning down was extremely important for the state granary. Many historical state granaries were built with thick rammed earth walls. In addition, building thick city walls to protect a series of state granaries was also quite common in history. Such kind of fort-shape granary complexes was named as granary-city（仓 城）in ancient China.

iii.Accessibility. Generally, accessibility was quite important for state granaries. The stored grain of state granaries was mostly shipped from various areas of the kingdom to the capital, thus the locations of the state granaries were generally close to the rivers. Rivers provided most convenient and effective transportation of huge and heavy load. Related to the increase controlled regions, the numbers and distribution of state granaries also increased during the following dynasties.

iv.Unified building forms. According to archaeological findings and laws enacted in the respective period, state granaries erected during a dynasty were inclined to be built following a common pattern. I believe that such a feature was mainly due to the requirements of budget control. Moreover, it can also facilitate the management of state granaries. Extreme examples were the state granaries of the Ming dynasty. Nearly all of the state granaries all over the Ming Empire were asked to be built in a unified form. Aiming at unifying the building forms of state granaries, the imperial administration of the Ming dynasty devoted to building a set of strict building regulations about state granaries. More details can be seen in chapter 3.8.1.

With the expansion of the country, the state granary generally differentiated into different types in the following thousands of years. The types of state granaries of different dynasties varied mainly due to the change of tax system and granary management methods among dynasties. Such as in Tang dynasty (618-907), when state granaries consisted of the following types: *Tai Cang* (Grand granary, 太 仓), *Zheng Cang* (Major granary, 正 仓), *Zhuangyun Cang*(Transfer granary, 转 运 仓) , *Jun Cang* (Military granary, 军 仓) , and *Cangpin Cang* ('ever-normal' granary[12] , 常平仓) (杨芳 , 2011, p. 16). While in Ming dynasty, state granaries consisted of the following types: *Jing Cang* (Capital granary, 京仓), *Shuici Cang* (Transfer granary, 转运仓), *Cangpin Cang* [13] ('ever-normal' granary, 常 平 仓). Nevertheless, these state granaries can be mainly divided into three types according to their function: granaries for storing grain for salaries of government officials and military, granaries for transit transportation, and 'ever-normal" granaries served for controlling and stabilizing the grain market.

2.2.2 State granary of the Shang dynasty

Archaeological discoveries suggested that two different building forms were executed in the construction of state granaries during the Shang dynasty: pit and cylinder granary.

A great number of pits, which were believed to be part of a state granary complex, were found on an ancient city site: *Zhengzhou Shang City* (河南省文化局文物工作室 , 1959, p. 9)[13]. These pits were far larger and deeper than the pits of the Neolithic period. Some of them can even reach 8–9 meters deep (河南省文化局文物工作室 , 1959, p. 10) (Fig. 2.4).

The cylinder granary is the major form of the above-ground granaries in early Chinese history. In the ancient book *Liji*, this type

12. Ever-normal granary(常 平 仓):The main function of this type of granaries is to keep the supply of grain stable, to stabilize the market price of grains, and to protect cities from famine.

13. In some Ming official documents, Cangping Cang was also named as Yubei Cang (预备仓).

14. *Zhenzhou Shang Chen*(郑 州 商 城), was an ancient city site now covered by the modern city Zhenzhou. It is also called as Erligang city. According to the later investigations, the ancient city should be surrounded by a roughly rectangular wall (Wiki, 2018).

15. Book of Rites or Liji (礼记) is a collection of texts describing the social forms, administration, and ceremonial rites of the Zhou dynasty (770–255 BC).

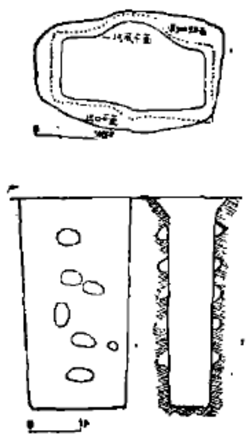


Fig 2.4 A grain pit of Zhengzhou Shang City. (source: 杜葆仁 , 1984，p307)

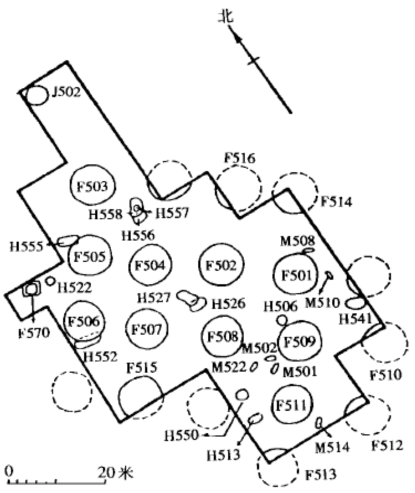


Fig 2.5 A group of *Qun* in Dongxia Fen. (source: 程平山 , 1998,p75)

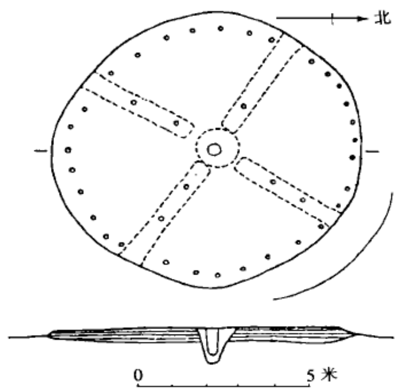
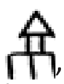


Fig 2.6 A *Qun* remain in Dongxia Fen. (source: 程平山 , 1998,p75)

16. Oracle bone script (甲骨文) was a form of Chinese characters carved on oracle bones. It is the earliest known Chinese writing.

of granaries was named as *Qun* (困). According to an archaeological report, 40–50 *Quns* were found to be gathered densely in a Shang dynasty city: *Dongxia Feng*(东下冯) (程平山 , 1998, p. 77) (Fig. 2.5). The sizes and forms of those *Qun* were nearly unified, and the interval spacing between them were similar as well. The archaeological remains displayed that the general diameter of *Qun* is between 8.5–9 meters (Fig. 2.6). This scale was much larger than the later ordinary *Qun*. The archaeological report shows that there are four short rammed-earth foundations inside each *Qun* remain. Some scholars suggested that this should be the bases of the partition walls inside the *Qun* and they might also act as the internal supports for the exterior wall (ibid.). Along the outline of each *Qun* remains, there were a series of small pillar holes dug into the ground with a short interval between each other. Although the archaeological scholar believed that the exterior walls of these *Qun* should be rammed-earth walls. However, these out walls could be a type of wattle and daub wall, at least according to the tracks of these small pillar holes. Cheng have suggested that a central pillar was originally erected in the middle of each *Qun* to support the roof, due to the fact that the central pillar holes were inside the building sites （程平山 , 1998, p. 74). Such types of granaries were used in the following millennia. The granaries with a similar form can still be found in the mountainous areas of Southwestern China. We will be coming back to that in Section 4.2.

2.2.3 Private granary

Oracle bone script[16] can provide us with some further information on the building forms of granaries of the Shang dynasty. As a type of pictographic writing, oracle bone scripts mainly represent the simplified images of the items which they refer to. The Chinese character of the granary, *Cang* (仓), was written as  in oracle bone script system. This character delineated a small building with a door. Another Chinese character "*Jing* (京)" also can refer to a special type of granaries. Their bone script character was carved as , representing a small building standing on a platform elevated by posts. This script is similar to the carving image of the granary found in *Xiantan Miao* site of Neolithic period. Can we assume that these oracle bone scripts reveal building shapes of small private granaries of the Shang dynasty?

2.3 The Zhou dynasty (ca. 1046–256 BC)

Following after the Shang dynasty, Zhou kingdom was established in the middle and lower Yellow River valley. Comparing to the former dynasty, the governing region of this Kingdom expanded in early Zhou dynasty . It was still confined to nowadays' Northern China. Accompanying the decline of the central government power throughout the mid-Zhou dynasty (771 to 476 BC), a series of vassal states were set up one after another along the Yellow River Basin and Yangtze River basin. They were comparatively independent city-states. In order to compete for more interests and territories, conflicts and wars were frequently carried out between two states or even several states.

According to the ancient book *Zhouli*[17], there were four major types of granaries used during this period: *Qun(* 囷), *Jiao* (窌), *Cang* (仓), *Cheng*(城). *Qinding Shousi Tongkao* (钦定授时通考) explained that *Qun* refers to cylinder granary, *Jiao* refers to storage pit, *Cang* refers to granary with a rectangular ground plan, and *Cheng* refers to granary-city, a granary complex.

2.3.1 State granary

Seen against such a volatile background, state granaries had become a key factor of war. Literature records on state granaries had increased during this period. According to *Zhouli*, a specialized agency for managing state granaries had already been established at that time. Qin state had even formulated a specialized regulation for the state granary management: *Canglv* (Granary Law, 仓 律)[18]. According to these laws, lots of state granaries were built not only in the capital but also in important towns during the Warring States period (481 –403 BC).

The underground pit was still the major storage building form in the middle and lower Yellow River Basin during the Zhou dynasty. Comparing to the Shang dynasty, the scales and depths of large pits of the Zhou dynasty had been further developed. Seventy-four large grain storage pits were unearthed in the ancient capital Luoyang, Northern China (Fig. 2.7)(洛 阳 博 物 馆 , 1981, p. 55). Supposed to be part of one large state granary, they were all similarly designed and constructed (Fig. 2.8). Such a pit was around 10 meters deep, with a circular opening of 10 meters in diameter. The internal wall of the pit was originally composed of several layers of different materials. From outside to inside there were mud mixtures, wooden planks, chaff and woven mats (洛阳博物馆 , 1981, pp. 57-58). I suppose that such kind of multi-layer wall structure serves two main functions: water-resistance and moisture absorption. The two layers of mud mixtures on the base of the internal wall were mostly for water-resistance (刘建安 , 2005, p. 188), while a 40 cm thick layer of chaff between the wooden planks and woven mat provides moisture absorption.

Granaries above ground were also built as state granaries in this

17. *Zhou li(* 周 礼): Rites of Zhou is actually a work on bureaucracy and organizational theory. It was supposed to be composed during the Warring States period (481 BC to 403 BC).

18. *Canglv*(Chinese: 仓 律) was an ancient regulation of Qin state originally recorded on Bamboo slips. The original pieces were uncovered at Yunmen, Hubei in 1975.

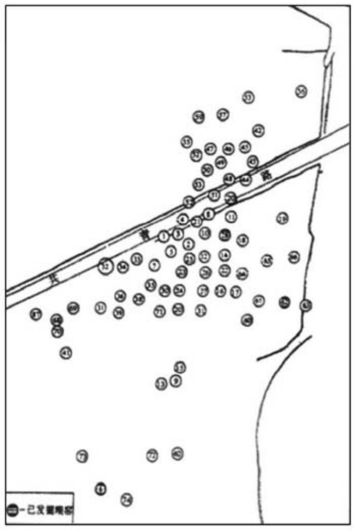


Fig 2.7 The plan of a group of storage pits of Zhou dynasty in Luo Yan. (source: 洛阳博物馆 , 1981,fig.05)

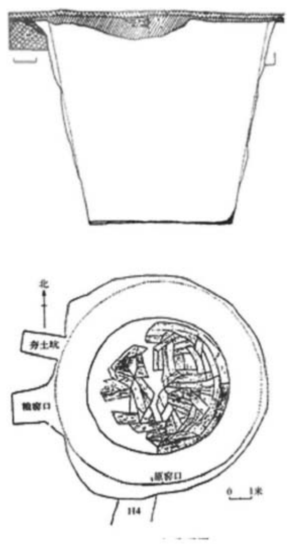


Fig 2.8 The section and plan of a storage pit in this archaeological site. (source: 洛阳博物馆 , 1981,fig.06)

period. An archaeological finding of a large above-ground granary site was found in South China. It was located in Xingan, Jiangxi, South China. According to the large scale of this site and the surrounding remains of city walls, it is believed that this granary could have been a state granary (杨日新, 1988, p. 44). The original form of this granary is supposed to be a rammed-earth building with a rectangular plan: 61.5 meters long, 11 meters wide (ibid.). This is the earliest example of granaries with rectangular plans. A group of crisscrossing channels was found to be dug along the inner ground of the granary. This was seen as a primitive method to improve air ventilation under the wooden floor of an enclosed space (ibid.).

2.3.2 Private granary

Based on the study of pottery granaries of the mid-Zhou dynasty, we can assume that *Qun* might be the major form of private granaries among the lower nobilities' and wealthy civilians' families in the Yellow River Basin during that period (Fig. 2.9).

During the mid-Zhou dynasty, pottery granaries became one of the most common types of funerary objects. Generally, they have been found in some graves of lower nobility and wealthy civilians among the Qin state territory(秦国) (张颖岚, 1999, p. 369)[19]. It was originally based on the requirement of replacing the former expensive ritual bronzes with cheap clay models in funerals (张颖岚, 1999, p. 375).

19. Qin state(秦 国) had occupied a vast region between the middle and upper Yellow River Basin to the middle Yangtze River Basin in this period.

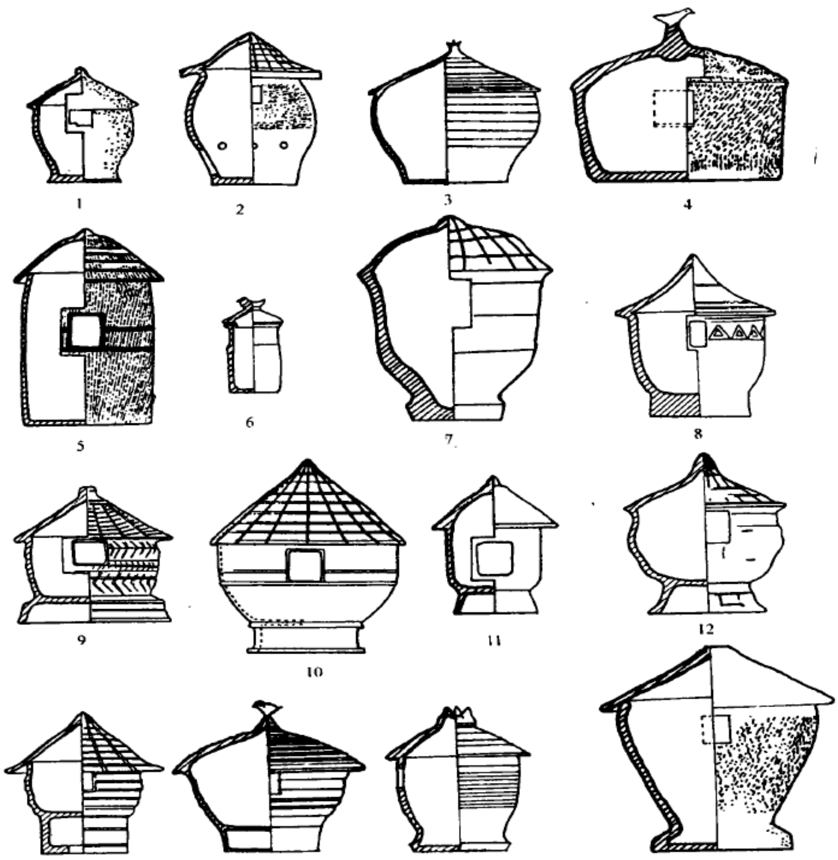


Fig 2.9 Pottery granaries found in tombs of mid-Zhou dynasty. (source: 张颖岚, 1999, p.366-367)

Generally the pottery granary not only acted as a symbol of the wealth of the dead, but also preserved food for the owner of the grave. Therefore, pottery granaries can be seen as miniature models of the real granaries of that period. According to the social status of these tomb owners, we can speculate that these clay granary models mostly represent private granaries of the lower nobility and wealthy civilians in that period. They were all above-ground granaries. These pottery granaries were cylinder granaries covered with roofs; in other words, they are all *Qun*. This finding suggests that *Qun* might have been a common form of private granary of the lower nobility and wealthy civilians in that time.

What kind of building material was used for building a *Qun* in this period? In the early granary models of Mid Zhou dynasty, rope patterns, regular streak marks, and oblique-crossing patterns were the common decorative patterns carved on the surfaces. It is likely that these patterns represented the building materials of *Qun*. Thus, one possibility is that these granaries were built with woven walls and covered with straw (张锴生, 1986, p. 99). Woven walls were made from bamboo or wooden branches, and they can be daubed with mud mixture for improving their sealing performance and fire resistance. An ancient agriculture book Simin Yueling of the Han dynasty suggested that farmer should daub their *Qun* in September in order to prepare the coming harvest. This further proves that wattle and daub construction might be the main wall material of *Qun* at that period. Such woven constructions are still applied in some simple rural granaries nowadays, such as some traditional granaries of Guizhou. The application of woven walls in the construction of Qun can also explain why the ground plan of *Qun* is round.

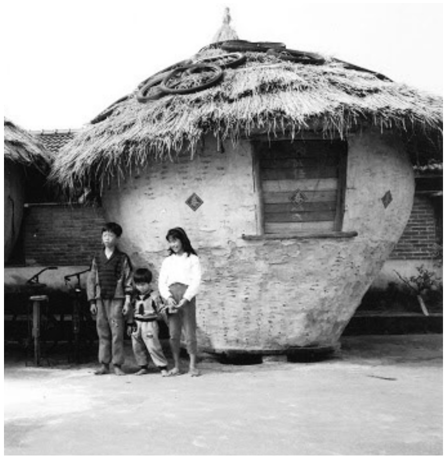


Fig 2.10 Traditional granaries of Taiwan. (source: https://tingwriter3.pixnet.net/blog/category/1679398/2,2013)

The bodies of some *Qun* models resembling inverted cones are shown in image Fig. 2.8. This could be seen as a method to prevent the base of a wattle and daub wall of a granary from being destroyed by rain in short time. This feature could also be found in nowadays' *Qun* in Taiwan (Fig. 2.10). In addition, adding a low basement might also be a common method applied to protect the wall base of a *Qun* in Zhou dynasty, as it is shown in the pottery granaries. The main consideration behind these designs was the same: extending the service life of a granary built with earth walls.

2.4 The Han dynasty (202 BC–9 AD; 25–220 AD)

In 202 BC, soon after the collapse of the Qin empire (221–207 BC), the Han dynasty was established. The political centre of the Han empire was still in the Lower Yellow River Plain. Meanwhile, the central government was eager to control more land. Thus,

20. Mingyue Kingdom (闽 越 国) was an ancient kingdom in nowadays Fujian province in southern China. Its inhabitants were groups of indigenous non-Chinese tribes called the Baiyue. The kingdom lasted from 334–110 BC.

21. Nanyue (南 越) was an ancient kingdom that covered parts of northern Vietnam and the modern Chinese provinces of Guangdong, Guangxi, and Yunnan. Nanyue was established in 204 BC after the collapse of the Qin dynasty by Zhao Tuo, then Commander of Nanhai.

22. Sub-granary: the major elements of the granary city. Each sub-granary was an independent building for storing grain. As a granary city was usually seen as a whole granary, the term 'sub-granary' was used to name these elements of the granary city, in order to avoid confusion.

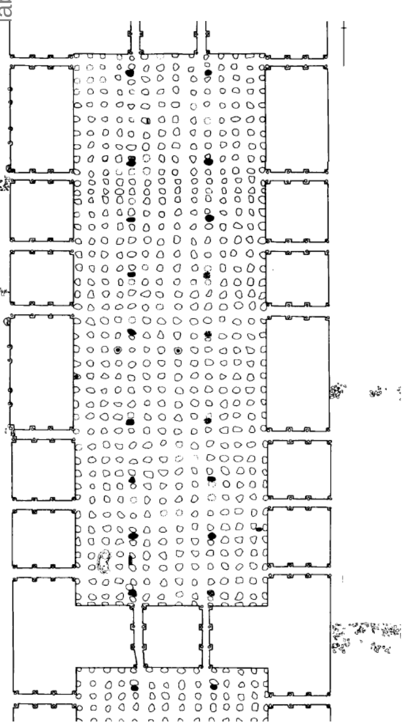


Fig 2.11 Plan of a part of Baiwang Dan granary in Fenxiang.(source: 田 亚 岐, 2005, Fig.3)

the territory of the empire continued to become expanded in this period. A series of small kingdoms on the original southern border were annexed and became part of the Han empire, including *Mingyue* Kingdom[20], and *Nanyue* Kingdom[21]. In this period, the extensive application of iron tools had yielded a large increase of agricultural output, thus leading to economic prosperity and population growth.

2.4.1 State granary

The scale of the state granaries of this period increased together with the expansion of the empire. Additionally, a special type of state granaries had been developed in the Han dynasty: *Changpin Cang*, so-called ever-normal granary (杨芳 , 2011, p. 15). Starting with the Han dynasty, these ever-normal granaries became important components of the state granary system in China for the coming millennia.

The granary-city (仓 城) became an important layout form of the state granary in this period. Take the Jingshi granary in Shanxi, for example. It used to be a granary-city consisting of six sub-granaries (陕西考古研究所 , 1990)[22]. Meanwhile, archaeological reports about granary ruins of the Han dynasty suggest that above-ground granaries and semi-basement granaries were the two major forms of state granaries (田亚岐 , 2005, p. 22).

The discovery of the *Baiwang Dan* granary (百 万 石 仓) site could provide some further information on the above-ground state granaries (Fig. 2.11). The site of *Baiwang Dan* granary is located in Fenxiang, Shanxi Province, Northern China, close to an ancient port of the Han dynasty (田亚岐 , 2005, p. 22). The site was selected mainly for transportation convenience. Studying the remains, we can deduce that the granary must have been a long rectangular building, 216 meters by 33 meters, strongly constructed, and providing a raised floor. This building was nearly 10 times larger than the Xinggan granary of the Zhou dynasty. There were two rammed-earth walls inside the building which divided the whole building into three equal units.

Originally, the granary was closed on all sides by 5.7 meters thick rammed-earth walls. Rammed-earth wall was the most common wall material among the diverse types of buildings in the Han dynasty. However, the thickness of the rammed-earth walls of the granary was much thicker than most of the other types of buildings which we already know from this period. In the same period, the thicknesses of the walls of Halls of *Changle* palace were between 1.3 to 3.5 meters (雷 繁 , 2013, pp. 80-82). Such thick rammed-earth walls might be a result of constructing a massive form. But it might also be developed against great side thrust from the inner stored grain, due to the structural requirement of granaries. As it was in Europe, stone granaries were equipped with thick walls and even large buttresses to resist against side thrust risen by the weight of the stored grain (Rickman, 1971, pp. 2–3). Inside the building, there were two types of stone pillar bases on the ground. The larger stone bases were supposed to be the pillar bases of the inner wooden roof structure. And the smaller ones were assumed to be piers for supporting the floor beams. This led to a speculation that the inner floor of the granary was originally a raised wooden floor. This speculation was nourished by a series of openings at regular intervals discovered along the wall bases promoting air ventilation under the wooden floor, aiming to bring humidity and heat produced by the stacked stored grain out of the granary. Another such kind of example is the *Hua Cang* (华仓) located in Huayin, Shanxi, Northern China. From the archaeological reports of these two granaries, share many similar features (Fig. 2.12).

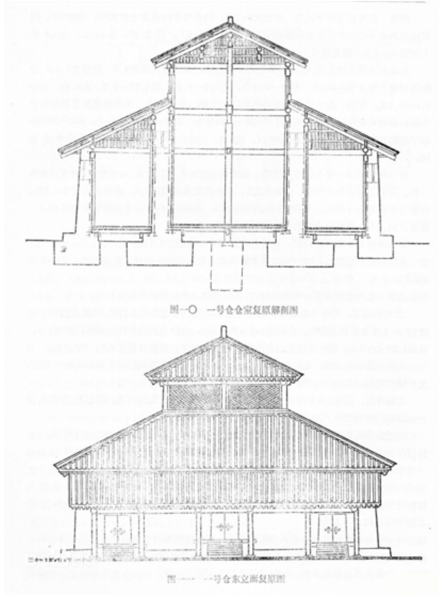


Fig 2.12 Reconstruction section and façade of Hua Cang in Huayin, Shanxi. (source: 陕西省考古研究所华仓考古队 , 1982,p31)

2.4.2 Private granary

Compared to previous dynasties, archaeological reports concerning private granaries of the Han dynasty largely increased. Great numbers of pottery granaries, carved brick images, and archaeological remains help us to build a comprehensive impression on a variety of types of private granaries in the Han dynasty. Among them, pottery granaries contributed the most. According to related statistics of archaeological reports, the tradition of burying pottery granaries in graves gradually spread from the former Qin state (the current middle Yellow River Basin) to other regions of the Han empire (吴晓阳 , 2013, pp. 4,11,12). And the forms of clay granary models largely increased in this period. There were three major types of private granaries in Han empire: pits, half-dug granaries, and above-ground granaries. There was not any archaeological finding of the private grain storage pits of the Han dynasty. Only literature resources indicate their existence (张 玮 , 2012, p. 77). The following discussion will mainly focus on half-dug granaries and above-ground granaries.

The pottery buildings and graves of the Han dynasty also indicate grain storage methods in the families living during the Han dynasty. Since tombs were seen as owner's houses in their hereafter world they can partly reflect the situation of their real dwellings. Firstly, many archaeological reports about Han tombs mention the same phenomenon: several pottery granaries filled with different species of cereals were found inside one tomb. This might indicate that an ordinary family of the Han dynasty might have built generally more than one granary or storage container in reality, thus they could store different species of cereals in different containers.

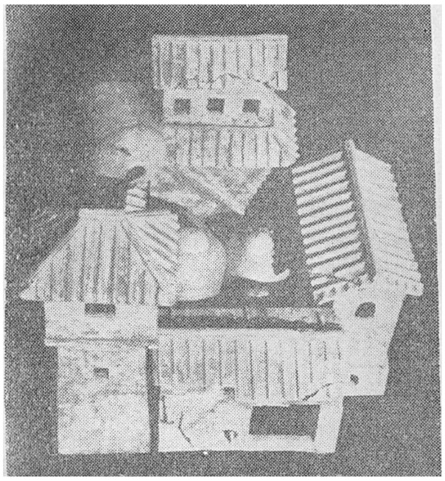


Fig 2.13 A clay courtyard house model discovered in Zhenzhou. (source: 张 松 林，1985,fig.1)

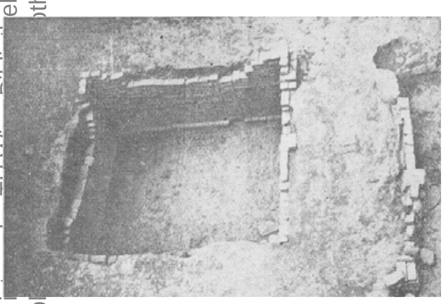


Fig 2.14 A half-dug granary with brick walls found in Luoyan. (source: 郭宝钧，1956，fig.1-

Secondly, granaries of one family can appear different forms in the Han dynasty, according to the combination of the pottery courtyard house and pottery granaries. A courtyard house model was discovered in Zhenzhou, North China (Fig. 2.13). It consisted of watching tower, kitchen, hall, a two-floor granary and five *Qun* (张松林，1985, pp. 7,8). Zhang Wei carried out a study on the related archaeological reports, he then suggested that these minor pottery granaries might represent minor indoor grain storage containers, while the large pottery granary should present the main granary of the family (张玮，2012, p. 94).

2.4.2.1 Half-dug granary

The archaeological reports indicate that half-dug granaries were mostly built in North China during the Han dynasty. The plans of such type of granaries could be square or round. A group of half-dug granaries was uncovered in Han residential site remains in Henan, North China. Archaeologists suggested that some of them were built in the western Han period, and some were built in the Eastern Han period (郭宝钧，1956, pp. 20,22). The underground parts were built in different materials: the semi-basement granaries of western Han were mainly built with rammed earth, while these of Eastern Han were mainly built with bricks (Fig. 2.14). This could be related to the development of brick technology in Eastern Han period. However, these semi-basement granaries shared similar features: the inner floors of the granaries were generally 0.5–1.7 meters lower than the ground, and they used to have above-ground structures. Several stone pillar basements found inside the granary remains suggested that they should be originally covered by wooden roof structures. The invention of such type of half-dug granaries might be due to the requirement of improving the accessibility of the storage pit.

2.4.2.2 Above-ground granary

Without any above-ground granaries remaining from this period , researchers had to learn to read and interpret information about the forms and building technologies of Han above-ground private granaries from pottery granaries and carved-brick images. Researchers with different academic backgrounds have proposed various classification methods for these pottery granaries. However, none has been accepted and implemented as standard until now. According to building forms and building technologies shown in these pottery granaries and images, we here classify the above-ground granaries of the Han dynasty into three major types: *Qun* (cylinder granary), *Cang* (Cubic granary), and *Ganlan* granaries (elevated granary).

2.4.2.2.1 *Qun* (cylinder granary, 囷)

According to the large number of pottery cylinder granaries discovered, it is likely that *Qun* was the most common building form of storage buildings among ordinary families in the Han dynasty. Not only in the mid and lower Yellow River Basin of North China, but pottery cylinder granaries were also found in some places of South China. Generally, the pottery cylinder granaries of the Han dynasty of North China show features different than those found in South China. They also differ from the pottery cylinder granaries of the previous Zhou dynasty.

In Northern China, most of pottery *Qun* of the Han dynasty was provided with openings on tops of the pottery , and some were also equipped with lids (Fig. 2.15). This style of pottery is quite different from the pottery cylinder granaries of the Zhou dynasty. They mostly had openings on their walls. Although some pottery *Qun* with top openings are also closed with roofs, I would be more inclined to suggest these were due to the requirement of the artistic decorations. The change of the position of the opening might suggest that part of *Qun* turned into indoor storage containers during the Han dynasty. Some pottery cylinder granaries own both top openings and additional openings on the lower parts of their walls (Fig. 2.16). This might be developed under an idea similar to that of storage silos. Meanwhile, grain silo models were also found in the tombs of the Han dynasty (for further, see Section 2.4.2.2.3).

Meanwhile, the pottery *Qun* of South China mostly presents more features of outdoor buildings. Much pottery *Qun* of the Hunan province was elevated by short piers, while the pottery granaries of Guanzhou and Guangxi were mostly supported by high posts. The latter part were regarded to present *Ganlan* granaries, to be explained in more detailed.

Fig 2.15 A clay *Qun* with an opening on its top.

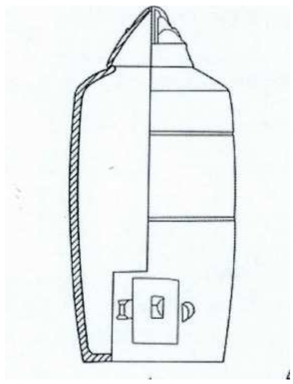


Fig 2.16 A *Qun* with an opening on its base. (source: 李桂阁 , 2005,p83)

2.4.2.2.2 *Cang* (Cubic granary, 仓)

Cang was used to name the granary with a rectangular plan in some literature of the Han dynasty (Fig. 2.17). It is also the general name of granaries in Chinese. Based on the archaeological reports related to *Cang* models, it shows that only one *Cang* model can be found in one Han tomb in most cases. The status of the tomb owners of the tombs with *Cang* models was generally higher than the status if an owner of tombs containing only *Qun*. Therefore, this suggests that *Cang* usually was the major granary of a family, offering larger capacity. And the families which built *Cang* probably were richer than the families which can only afford to build *Qun*. In addition, some *Cang* models were made of stone which is more difficult to

Fig.2.17

Fig.2.18

Fig.2.19

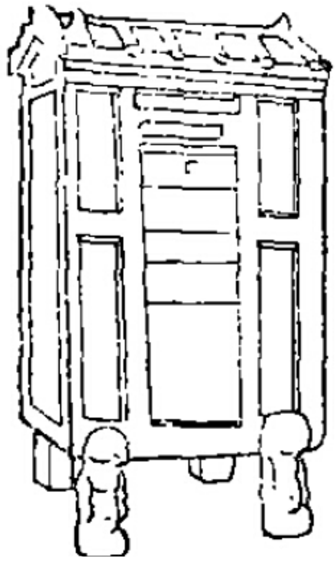


Fig.2.20

Fig 2.17 Fig 2.17 A tawny-glaze pottery *Cang* with roof monitors,Nanyang. (source: 河南博物馆 , 2002，p43)

Fig 2.18 A pottery *Cang* with raised floor, Lingbao. (source: 河南博物馆 , 2002, p45)

Fig 2.19 A two- storey clay *Cang*,Nanyang. (source: 河南博物馆 , 2002, p13)

Fig 2.20 A pottery *Cang,* Tongguan. (source: 王玉清 , 1961, p65)

work than pottery, while nearly all of the *Qun* models were made of pottery. This difference in material implies that the importance of *Cang* might be higher than of *Qun* in a family of the Han dynasty.

The earliest *Cang* model was found in a tomb of the early Han dynasty, much later than the first *Qun* model of Zhou dynasty (陕西省文管会 , 1977, p. 14). It represented a single-story granary. Then findings of tombs with *Cang* models increased among the tombs of the mid-late Han dynasty. This probably indicates that cubic granaries gradually became one of the main building forms of granaries since the mid-Han dynasty.

Starting with the late-Han dynasty, multi-storey granary models appeared as funerary objects in tombs (武玮 , 2006, p. 29). This might be the reaction of the real situation in that period. Due to the start of the land annexation activities in the mid-Han dynasty, nobles or the wealthy landlords gradually occupied enormous fields and built their own huge manors, especially at the middle and lower reaches of the Yellow River, North China. This led to the appearance of the huge private granary with large capacity. The multi-storey granary models became popular in the early Eastern Han dynasty, and forms of some became fantastic then. As there is no archaeological remain about such type of multi-storey granary, we can only suppose that some building forms of the found granaries might own realistic reference.

There was a special type of granaries that might have developed from multi-storey granaries in Eastern Han period: Silo. Some of them might own some similar building forms features with the ordinary multi-storey granaries, according to studies of pottery granaries. However, the application methods of them were quite different.

Studies of pottery granaries contribute some information about the building technology of cubic granaries of the Han dynasty:

i. Roof: The patterns of roofs of pottery granaries show that the majority of cubic granaries were covered with tiles in that period. Pitched roof and hip roof should be two main roof forms used in these granaries.

ii. Wall: Unlike pottery *Qun*, little information of wall construction can be obtained from the most of pottery granaries. However, decorative patterns on some pottery granaries suggest that wood panel walls had already been used as exterior walls of small granaries in the Han dynasty. The image Fig. 2.18 shows a glazed cubic granary uncovered in Shanxi, which dated from the late Eastern Han dynasty. The model depicts a small granary standing on six low basements. It is covered with a tiled gable roof. The detailed strip-shaped decorations on the surface of this granary model indicate that the walls of this granary should be wood panel walls (河南博物馆, 2002, p. 45). Another cubic granary model of Shanxi province shows similar construction details (陕西省文物管理委员会, 1961, p. 61).

iii. Foundation: Most pottery cubic granaries were based on low foundations or short piers. These features suggest that raising the floor was the main moisture preventing method applied in ordinary single-story granaries. Some pottery granaries indicate that the foundation of a granary can be one storey high, and ramps would be necessary for entering the granary as shown in Fig. 2.17.

iv. Door: Fig. 2.19 presents a door locking method: fixing sticks through rings on door jambs and doors. Such details were common

Fig 2.21 A image of a granary with a roof monitor, Heling Ge'er. (source: 吴晓阳, 2013, p.45)

Fig 2.22 A pottery Cang with a front porch, Zhengzhou. (source: 河南博物馆, 2002, p.44)

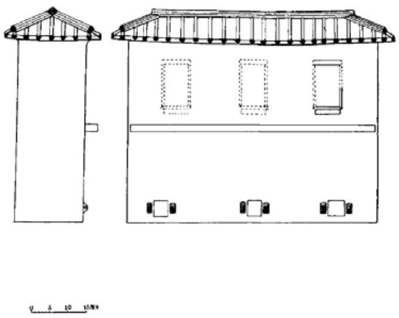


Fig 2.23 A pottery silo, Nanyang.(source: 河南省文化局文物工作队，1961，p.133)

to be found in pottery granaries of the Han dynasty. This could suggest that such a locking method was widely used in granaries of the Han dynasty. In the late Han dynasty, another type of locking method was invented. As is shown in Fig. 2.20, the opening of the pottery granary was closed with a series of horizontal planks which hold in grooves of two door jambs. There is a handle on the topmost plank. Thus it suggests that the door can be opened by removing the topmost plank (王玉清, 1961, p. 63). The decorative pattern of the pottery implies that it represents a wooden granary. These two door locking methods can still be found used in some wooden granaries of South China.

v. Roof monitor: Roof monitor began to be applied in the Han dynasty, shown in some pottery granaries and carved brick images (Fig. 2.21). The main function of the roof monitor is to provide lighting and to facilitate air ventilation in the large granary. Among brick carving images, we can notice that the openings of these monitors were usually decorated with oblique crossing patterns. This can be seen as a symbolic expression of woven bamboo fences, which were mostly added outside the windows to prevent birds from intruding into the granary. This construction detail was also recorded in the official construction manual of the granary of the Qing dynasty (鄂尔泰, 1737).

vi. Porch: Another common architectural component shown in some clay models of granaries was front porch, as to be seen in image Fig. 2.22. The front porch is originally designed in order to protect the entering space of the granary against rain. This facilitate grain transportation during rainy days. This design was also quite common among *Ganlan* granary models found in Guangxi and Guangdong. There humidity is high.

2.4.2.2.3 Silo

Shown by pottery granaries there was one special type of granary developed since the mid-Han dynasty: silo. The most significant feature of silo is two rows of openings in its frontage: large openings in the upper row, and smaller openings in the lower row. This special design aims at reducing labour costs on transportation. When storing grain into the silo, people open the up doors and pour grain into it. The lower doors should be kept closed during this period. When people need to take grain out from silos, they can simply open the lower doors and let the grain pour out automatically by the action of gravity. Such a design is quite useful for the granary especially when the amount of grain that needs to be transported is huge. Image Fig. 2.23 shows an early silo model unearthed in Henan, North China. This silo owns two layers of doors: three bigger doors on the second floor and three smaller doors on the ground floor. The bigger doors are for filling in the grain, while the lower small ones are for taking out the grain. The different sizes of these doors also reflect the different functions of these doors. There are pairs of bolts attached beside the lower door, which were used to lock the lower doors. The section drawing of the silo shows that the inner space of this granary was divided vertically into three rooms. This further suggests the special way of use of this granary.

Starting from the Eastern Han dynasty (25 AD–220 AD), the silo model of some certain regions had been developed into an impressing variant: the building complex consisting of silo and residence. They were mostly found in Jiaozuo, Henan, North China. The common characteristics of these building complex models are the arrangement of one or several silos on the basement of the complex, and one or several-storey high residential building above (Fig. 2.24). Forts or frontcourt can be added in some such types of models (Fig. 2.25). Some scholars explain such models may reflect a real special type of high-rise dwellings existing in Jiaozuo during the Han dynasty (武玮, 2006, p. 39). However, as there is not any remain of such type of building of the Han dynasty found up to now, it is hard to know whether such type of granary had ever really existed.

After the Han dynasty, the application of such a silo in granary construction was not get found any more in China.

Fig 2.24 A three- storey pottery silo, Jiaozuo. (source: 河南省文化局文物工作队，张保民 赵慧钦, 2016, p.22)

Fig 2.25 A seven-storey painted pottery storage building with bridge, Jiaozuo. (source: 河南博物馆, 2002, p.44)

2.4.2.2.4 *Gan-lan* granary

Fig 2.26 A bronze Ganlang granary, Hepu. (source: 梧州市博物馆 , 1977, p.72)

Fig 2.27 A pottery Cang with bamboo posts , Guangzhou. (source: 黎金 , 区泽 , 1958, fig.3)

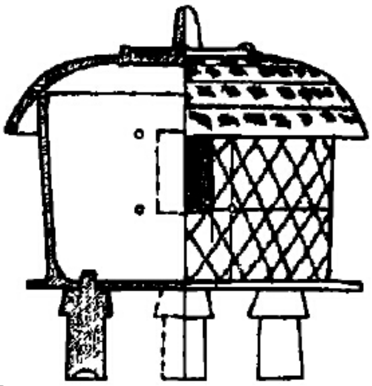


Fig 2.27 A pottery Cang with bamboo posts , Guangzhou. (source: 黎金 , 区泽 , 1958, fig. 3)

Accompanying with the southward expansion of the Han empire, the burial tradition of putting granary models into the grave was also brought to the new territory. A new type of granary models had appeared in the current Guangzhou and Guangxi areas since the mid-Han dynasty (Fig. 2.26). Such kind of granary models was made by either clay or bronze. Nearly all granary models of this region appear as *Ganlan* building, since *Ganlan* buildings are characterized by a raised floor supported by high posts. Unlike the granary models with raised floor in central China, the heights of the raised floors of *Ganlan* granary models were much higher. We can assume that Han granaries of this area mainly showed the same feature in reality. This feature might have been developed in order to adapt to the more humid climate and mountainous terrains in this region.

Some granary models were made by two different materials: the upper parts were made of clay or bronze, while their posts were made of wood or bamboo (黎金 , 1958, p. 42) (Fig. 2.27). This feature might imply that the real granaries of this region might have owned separate structures: their bodies of granaries were not fixed with their posts. And the materials used as their posts, wood and bamboo, are perishable materials. These features are consistent with the characteristics of nowadays' *Ganlan* granaries with earthfast posts as pillars. Thus I assume that *Ganlan* granaries with earthfast posts were used in these regions in the Han dynasty. Such types of granaries can still be found in nowadays' Laos and Thailand. There are also some evidences show such granaries were also used in Yunnan of China before the 1980s (for further, see Chapter 5).

Image Fig. 2.28 shows different decorative patterns on the surface of this clay model found in Guangzhou. They reveal building materials of the granary: a thatched roof and woven bamboo mat walls. Another interesting detail are tops of the posts: protruding caps, which acting as mouse guards. In a Han settlement remain of Gaoyao, Guangzhou, a special round wooden remain was also recognized as a mouse guard of a granary (杨豪 , 1983). It seems that round mouse guards were a type of common components of *Ganlan* granaries in South China in the Han dynasty. This tradition lasts until now. Cylinder granaries with thatched roofs and woven bamboo mat walls can still be found in some Yao villages in South China nowadays (for further, see Section 4.3).

2.4.3 Granaries in non-Han empire area

In areas with different building traditions, the forms of the granaries look different. In Yunnan province of South China on the southwestern border of the Han empire, there was an ancient

23 Dian Kingdom (滇 国) was an ancient kingdom established by the Dian people, an ancient group of indigenous non-Chinese metalworking tribes that inhabited around the Dian Lake plateau of central northern Yunnan, China from the late Spring and Autumn period until the Eastern Han dynasty. The Dian language was likely one of the Tibeto-Burman languages.

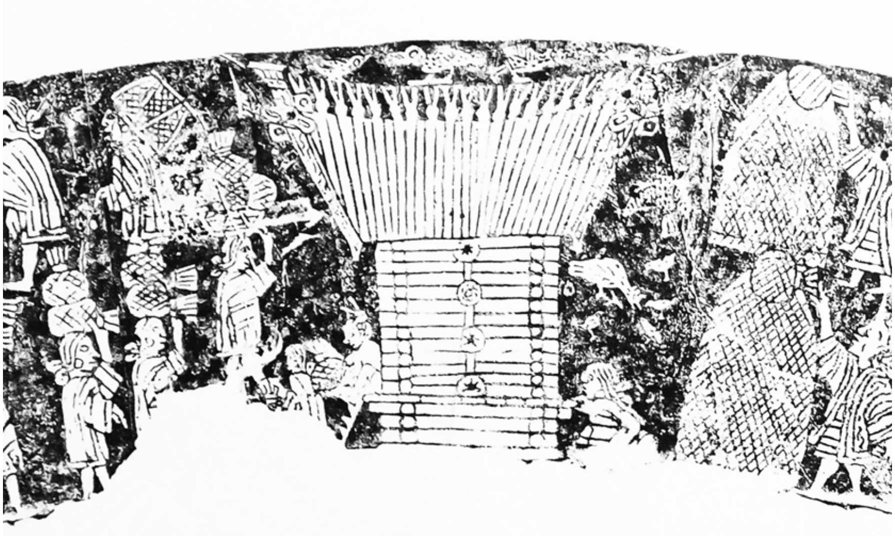


Fig 2.29 An image with a log construction granary, Jingning, Yunnan.(source: 云南省博物馆)

kingdom called the Dian kingdom (滇 国)[23]. The culture of the Dian kingdom was different from that of the Han region, including differences between their building traditions. From a carved image on a cowrie container (Fig. 2.29), we see that the granaries of Dian Kingdom were built as log constructions and covered with saddle roofs. This image also depicts another detail of these granaries. The floors of the granaries were lifted above ground. Without any doubt, this design intended to promote better air ventilation beneath the inner floor. The application of log construction in granaries continues today in Tibetan areas and among some other ethnic groups related to Tibetans. Log construction granaries can also be found nowadays in the Yunnan area.

2.5 The Three Kingdoms to the Tang dynasty (220–907)

Starting from the late Eastern Han dynasty, the economic decline during wartime and the introduction of Buddhism largely changed previous burial traditions. Very few granary models could be found in the graves after the Eastern Han dynasty. This reduces the information available on the above-ground granaries of later dynasties. Meanwhile, the archaeological excavation still provided some knowledge about the huge state granaries in North China from the Three Kingdoms dynasty to the Tang dynasty. Due to the long-term wars over hundreds of years, the sizes of state granaries continued developing in this period.

Apart from state granaries and private granaries, another type of granary appeared during the Sui dynasty (581–619): *Yi Cang* (public granary, 义 仓). Different from state granaries, *Yi Cang* was used only for disaster relief, mainly built and managed by local citizens. However, this type of granary was prone to be left abandoned due to lack of effective supervision (杨芳, 2011, p. 199). Thus these public granaries were usually quite short-lived buildings (for further on Yi Cang, see Section 3.8.2).

2.5.1 *Cangku Ling* (仓库令)

In Tang Code[24], there are special regulations on granary construction: "*Cangku Ling*" (Granary regulations, 仓库令). It was the first official regulation concerning the building forms of the state granary in Chinese history. In *Cangku Ling*, pits and above-ground granaries are presented as two major building forms of state granaries of the Tang dynasty. The code mentioned that people needed to select suitable building forms in granary constructions according to the surrounding conditions. One of these regulations describes rules of site selection: "all granaries should be built in a high and dry location. Channels should be built around the granary for draining… In the place where the soil is too humid which is unsuitable for building pits, then people can build an above-ground granary for storing"[25]. This ancient rulebook implies that an underground structure was the first choice for state granaries during the Tang dynasty.

2.5.2 State granary

Discoveries of several giant state granary complexes of the Sui-Tang dynasty (581-907） reveal some information about the layouts of state granaries of this period and the building technology of storage pits. Nearly all of the known state granary remains of the Sui-Tang dynasty were found in North China. This might be one reason that they were nearly all half-dug granaries and storage pits. The climatic conditions of North China are favourable, as it is much drier than South China.

In the Sui-Tang period, state granary complexes were mostly enclosed by thick city walls to form a defensive granary-city. As the large amount of stored grain was regarded as a key factor of nourishing the solders and thus succeeding in wars; granary complexes were thus built with the standards of fortresses. *Huiluo granary* (回洛仓), a large granary-city of the Sui dynasty, was located in a Northern area outside the capital Luoyang, next to a river. It was actually an independent fort. With a rectangular perimeter 1,140 meters long and 355 meters wide, the granary-city was protected by 17 meters thick rammed-earth walls (张婷瑜 , 2017, p. 23). The granary complex consisted of around 700 storage pits, drying squares, management offices, and cross-shaped transport passages . However, this granary-city was plundered and destroyed in the war during the late Sui dynasty. After this plundering , the following government of the Tang dynasty decided to build a new large granary complex *Hanjia* granary (含 嘉 仓) inside Luoyang city. This

24. Tang Code (唐 律) was a penal code that was established and used during the Tang Dynasty in China. Supplemented by civil statutes and regulations, it became the basis for later dynastic codes not only in China but elsewhere in East Asia. Created in AD 624 and modified in AD 627 and 637, it was promulgated in AD 652 with 502 articles in 12 sections and enhanced with a commentary (Tanglv Shuyin 唐律疏議) in 653. Considered as one of the greatest achievements of traditional Chinese law, the Tang Code is also the earliest Chinese Code to have been transmitted to the present in its complete form.

25. The original Chinese version of this section: 诸仓窖，皆于高燥处置之，于仓侧开渠泄水... 若地下湿，不可为窖者，造屋置之。

Fig 2.30 A reconstruction site plan of Hanjia Cang based on the archaeological report. (Source: 张婷瑜 , 2017,p66)

new plan was assumed to be a kind of reflection on the destruction event of *Huiluo* granary, as an isolated fort outside the main city is more vulnerable during wartime. Nevertheless, the construction of the pits and the layout arrangement of Hanjia granary were quite similar to those of *Huiluo* granary (Fig. 2.30)(张婷瑜, 2017, p. 47).

2.6 The Song dynasty (960–1279)

Since the mid-Tang dynasty, many Han immigrants constantly flooded to South China, such as in the lower reaches of the Yangtze River, Fujian, and Zhejiang, due to frequent wars in North China (韩茂莉, 2012, p. 58). The influx of these immigrants had promoted the rapid development of agriculture in these regions. The promotion of advanced agricultural technologies such as land reclamation and terraced field construction greatly enlarged the area of arable lands in South China (韩茂莉, 2012, p. 66).

In the early Song dynasty, the population of South China exceeded that of North China for the first time. This situation has continued to the present day. During the same period, the middle and lower reaches of the Yangtze River became the major grain-producing area of China, because of the ideal planting conditions for rice and the more advanced agricultural technology. However, the Chinese political centre was still located in North China in the Northern Song period; thus, most of the state granaries were also located in North China. Accordingly, most of the state granaries had to rely largely on supply from the lower reaches of the Yangtze River during this period. A great amount of tax grain from South China needed to be transported to North China by the Great Canal (韩茂莉, 2012, pp. 60-61).

2.6.1 State granary

Similar to the Tang dynasty's laws, those of the Song dynasty also included particular instructions about construction and management of the state granary. This part was also named as *Cangku Ling* (Granary regulations, 仓库令). The main part of the *Cangku Ling* of the Song dynasty was developed based on the same part of the Tang Code (杨清越, 2013, p. 63). According to this regulation, pit and above-ground granary were still the two main types of state granaries in the Song dynasty, apparently unchanged from the Tang dynasty's. Meanwhile, compared to the Tang Code, the granary regulations of the Song dynasty were given two more provisions: (1) planting willow trees and elm trees around the granaries[26] and (2) covering the interior floors of granaries with bricks. The first provision might be aimed at using trees to shade the granaries in order to reduce the temperature of the granaries. A second might be related to reducing the intrusion of moisture. However, according to an excavated state

26. In Tang code, this provision is 'do not plant anything on the free space between granaries.' (杨清越, 2013, p. 63).

granary of the Song dynasty located in Zhenjiang, these building manuals might have been observed so strictly in practice. The floor of this granary was found to be originally made of wood.

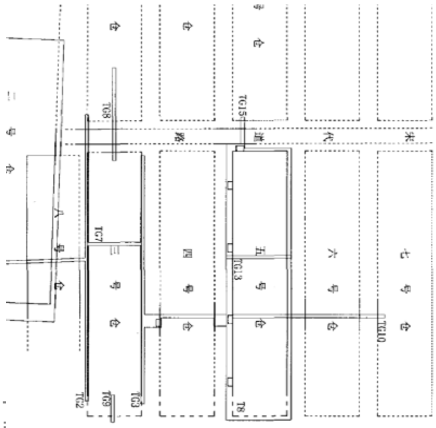


Fig 2.31 An archaeological site of a granary complex in Zhenjiang, Jiangshu. (source: 王书敏, 2011, p. 58)

Some sites of state granaries of the Sui dynasty had been continued to be used in the Song dynasty, such as *Liyang* granary (黎阳仓). The *Liyang* granary was one of the large state granaries built during the Sui dynasty. It is located in Junxian, Henan, North China. According to one archaeological report, it used to be a large granary-fort with an area of 85,800 m^2. Inside this granary fort, more than 90 storage pits of Sui and the Tang dynasty were thought to be buried beneath the earth floor of this area (马 晓 建 , 2015, p. 08). Meanwhile, some building remains dated from the Song dynasty suggest that some above-ground granaries were built directly above these pits during the Song dynasty. According to some inscriptions on these remains, these above-ground granaries were state granaries as well. Scholars have assumed that during the Song dynasty, people might firstly have infilled the previous storage pits with soil and rammed them into a stable foundation. Then they may have built above-ground granaries on this foundation (国家文物局 , 2013, p. 127).

Fig 2.31 An archaeological site of a granary complex in Zhenjiang, Jiangsu. (source: 王书敏, 2011, p. 62)

There is yet no concrete explanation of why people built above-ground granaries to replace former underground storage during the Song dynasty. One possible reason for this shift might refer to a change in the species of stored grain. Based on archaeological research, it is believed that stored grains of *Liyang* granary during Sui and the Tang dynasty should mainly be two species of millet: Foxtail millet and Proso millet. However, the stored grains of Liyang granary during the Song dynasty should be mainly rice, due to the change of the agricultural production area in this period. Under the same conditions, millet can be stored for longer periods than can rice without rotting. Rice's lack of longevity in storage means that granaries for storing rice needed to facilitate the connecting, filling and emptying of the storage. The storage must be emptied in shorter intervals and thus must demand more effective transportation conditions. Using above-ground granaries, it would be easier to get rice in and out. However, we have no support from the literature.

Based on the increasing requirements of grain transportation, some state granaries were built along the great canal during the Song dynasty. One excavated site of this type of state granaries is located in Zhenjiang, Jiangsu, South China. This archaeology site can provide us with some more information about the above-ground granaries of the Song dynasty. This granary was originally located close to a wharf of the Song dynasty (王书敏 , 2011, p. 61). It was assumed to be a small granary-city enclosed by walls. Inside this granary-city, 11 storage building sites had been found until now, which include two remaining sites of the Northern Song[27] and eight remaining sites of

27. The Northern Song Dynasty (960 - 1127) is an era during the Song Dynasty. The Southern Song (1127–1279) followed the last era.

the Southern Song (Fig. 2.31). According to the excavated site plan, the storage buildings of the Northern Song were built in the unified form, and granaries of the Southern Song were so as well. However, the scales of granaries of the Southern Song were smaller than those of the Northern Song.

The archaeological findings suggest that an original storage building of the Northern Song dynasty in this site should be 110 meters long and 29.5 meters wide (Fig. 2.32). Built on a 0.5 meters high rammed-earth foundation, it was speculated to have been enclosed with rammed-earth walls. The thicknesses of these walls varied between 1.3–1.7 meters.

Along the frontage of the building, there was a 4.2 meters wide veranda. This was to be used to increase convenience for transporting grain in the local humid weather. Such large granaries with front porches were named *Mingsha*（明厦）in *Nongshu*. It might already have been a typical style of state granaries in the Song dynasty.

According to the wall bases, the whole storage building was divided into three separate spaces by 1.7 meters thick brick walls. The eastern storage space is 25.8 meters along the longitudinal direction and 22.6 meters along the transversal direction. By the remaining stone column basements inside this space, we can deduce that inside the walls was a wooden framework supporting the roof initially. This framework comprised six bays in length and six bays in width. However, there was no more on-site evidence implying how people used such big spaces for grain storage in the Song period. Studying literature of Dunhuang（敦煌）, Wang Baozhu supposes that people created a kind of inner subdivision by putting large baskets for storing grain inside the large storage buildings in the late Tang dynasty and the early Song dynasty（王宝珠，2008, p. 39). This storage method contributes to facilitate the estimation of stored grain. Meanwhile, it might also facilitate air ventilation inside the granary. Maybe it would be the same in this granary.

Between the stone column bases, numbers of smaller stones are located inside the walls. They were assumed to have served as bases for supporting the floor beams of the granary. This finding implies that the inner floor of the granary should be a wooden floor elevated by lower floor beams and minor stone bases.

2.6.2 Private granary

During the Southern Song dynasty (1127–1279), emperors began to pay more attention to agriculture, aiming to increase agricultural efficiency to alleviate the problem of land shortages（张 铭，2015, p.

Fig 2.33 A granary in a 'Genzhi Tu' painting of Yuan Dynasty. (source: Arthur M. Sackler Gallery)

75). Meant to gain the emperor's favour, several paintings of this period depicted the scenes of agricultural production, including rural granaries. Considering that the land of the Southern Song dynasty was mainly in South China, the granaries depicted in these paintings should be rural granaries of South China. More specifically, these granaries should be granaries from Southeastern China in most cases, according to where the painters of these painting originated.

One such painting is " *Genzhi Tu* (耕 织 图)"[28]. It provides us with some information about the rural granaries of Southeastern China at that time. Shown in painting Fig. 2.33, the granary should be equipped with a porch along the frontage. Inside, the granary storage rooms were formed by horizontal wooden planks put in between pillars. By removing part of the wooden planks, an opening could be produced on a particular wall. Then people could infill rice into the storage room through this opening. The stored rice was stacked directly on the floor of the room. For this reason, people could only remove the upper wall planks. There are numbers marked in every removable plank of this particular wall. This is a traditional way of installing such wall planks in a certain order. This method lasts until nowadays. According to another detail shown in the painting, the floor of the storage room of the granary is lifted above the ground. This execution reminds of the state granary of Zhenjiang, which also with an elevated wooden floor.

28. The original version of *Genzhi Tu* was painted by Lou Cou in mid-12 century. Then Chen Qi copied it in the mid-13 Century. Since the original version by Lou Cou was already lost, the Chen Qi's 'Genzhi Tu' was used in this article.

2.7 The Yuan dynasty (1271–1368)

After the chaos of the early Yuan dynasty, Mongolia conquerors decided to continue the advantageous agricultural policy of the previous dynasty in this period. Some emperors have encouraged officials to promote the development of agricultural technology (王培华, 2005, p. 55). In the late-13th century, a county magistrate of South China, Wang Zhen, compiled the local advanced agricultural knowledge into the book: *Nongshu* (农书). The illustrations of this book depicted a great amount of agricultural equipment, including varying items used in storing grain. Aiming at promoting advanced agricultural knowledge, these methods of storing grain were mostly intended to instruct ordinary farmers.

In his *Nongshu*, Wang Zhen described two types of storage containers and classified them into two types: granary (original text: 仓廪门) and basket (original text: 篠蒉门). Yu Xiuling explains that this classification criterion divides according to the usage of the container. One is for long-term storage, another for short-term storage. However, according to that classification, baskets were found to be used in the large granaries of the Tang dynasty and in some dwellings of ethnic groups even today (王宝珠, 2008, p. 39); I would like to suggest that the classification should be made according to whether the container is located outdoors or indoors.

Wang Zhen has emphasized in his book that people need to choose the right way to store grain according to varied local climates. Due to the dry climate of North China and that the main crop there was millet, farmers of North China can choose underground pits for storing their harvest (王祯, 1981). Under the wet climatic conditions in South China, people needed to build granaries with elevated floors called *Jing* (京). According to the illustration of Jing in this book (Fig. 2.34), it is a small wooden granary with panelled walls and low feet.

Wang Zhen introduced a special equipment in the chapter "Granary", *Guzhong* (谷盅) as a method of reducing the moisture in the granary (Fig. 2.35). *Guzhong* is a type of bamboo basket, thin and tall. It can be put into the grain stack. According to my fieldwork, this kind of equipment has already vanished.

Another special item mentioned in Nongshu is *Gugui* (谷 柜). The image in Fig. 2.36 shows a special type of granary comprised by numbers of separate wooden frames with a unique characteristic. Wang Zhen has described that it can be put in the interior space and was movable. Moreover, the most important advantage of this *Gugui* is that its volume could be adjusted according to the amount of harvest by adding or taking away wooden frames. It is believed to be a good way to save interior space. Such a granary had never been recorded in previous literature. It might have been invented in the Yuan dynasty or in the late Song dynasty. This style of granary can be found in Mid-Fujian even today. From the perspective of carpentry technology, the invention of *Gugui* reflects the development

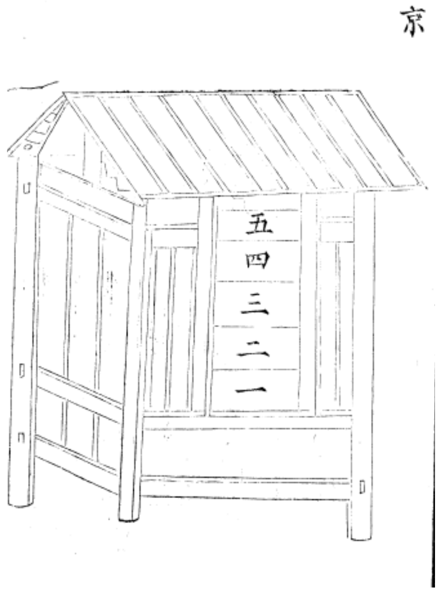


Fig 2.34 The image of a *Jing* recorded in *Nongshu.*


Fig 2.35 The image of a *Guzhong* recorded in *Nongshu*

Fig 2.36 The image of a *Gugui* recorded in *Nongshu*

of wooden working precision at that time. To stack numbers of separate frames together and to keep the outlines of them in one line requires that each contact surface of these frames should be done perfectly flat. This task can be done successfully only by using the plane. The prototype of the plane was introduced in China in the Southern Song dynasty (李浈, 2015, pp. 84-85). Thus, we have reason to attribute the invention of *Guigui* to the introduction of the plane in that period.

2.8 The Ming–Qing dynasty (1368–1912)

In the Ming dynasty (1368–1644), the Han people re-established their rule in China. Starting from 1644, the Manchu people from Manchuria ruled China up to 1912, after the decline of Ming empire. It was the Qing dynasty. It is common sense that many policies of the Qing dynasty continued the tradition of the Ming dynasty, including the tax system, official building[29] project management, and so on.

2.8.1 State granary

In the Ming dynasty, the imperial administration set up a series of exhaustive regulations on state granaries. Three types of state granaries were prevalent in the Ming dynasty: *Jing Cang* (Capital granary, 京仓), *Shuici Cang* (Transfer granary, 转运仓), and *Cangpin Cang* (Ever-normal granary, 常平仓).

2.8.1.1 Standardization of the state granary: *Jian* (间) and *Ao* (廒)

In the Ming–Qing dynasty, the design and construction of official buildings became more standardized. State granaries[30] belonged to official buildings. Aiming at controlling the budgetary expenses of the construction projects strictly, officials of the central government tried to formulate a series of unified specifications for all construction works of state granaries in the whole empire. These specifications then composed a kind of building regulation covering the different layers of requirements for building a granary. It included the site selection, the layout, the construction details, and the exact quantity of building materials. Moreover, it also provided several methods of handling moisture.

As a step of building standardization, Ming officials suggested unifying the sizes and layouts of state granaries[31]. Zhang Chaorui, an official of the mid-Ming dynasty, proposed a scheme of building regional granaries: *Changao Yi* (仓 廒 议). He suggested even the

29. Official building (官式建筑) is a noun used in Chinese historical buildings. It is referred to the historical buildings which were built by the government or the military.

30. In Ming dynasty, the types of state granaries can be classified into two major types : central granary and regional granary. Central granaries included capital granaries (京 仓)and transfer granaries (水 次 仓). Regional granaries inculded reservation granaries.

31. Most of these suggestions were for building regional granaries.

smallest town should own four granaries. An official granary of a town should be comprised of rammed-earth enclosure walls, an entrance hall, a residence building for guards, and many storage buildings (徐光启 , 1639). The storage buildings should be laid on both eastern and western sides.

The storage building is called "*Ao*" (廒) in most of the government documentation of the Ming–Qing dynasty. In the mid-Ming dynasty, the *Daming Huidian* (Code of the Great Ming Dynasty, 大明会典) prescribed that all storage buildings of the state granary should be built in accordance with a standard pattern so-called standard *Ao* (样廒) (大明会典 , 1587).

However, the uniform size of storage buildings cannot adapt flexibly to the varied storage capacity requirements in different cities all over the empire. Thus, Zhang Chaorui suggested that the size of the storage buildings should be more flexible. According to his conception, the types of the standard *Ao* increased into three. They were comprised of 3, 5, and 7 *Jian* (间), respectively (Fig. 2.37). Each *Jian* of a storage building was of nearly the same size. Thereby Jian became another standard component of the state granary. In many governmental documents, Ming officials use the number of *Jian* to describe the scales of the granaries.

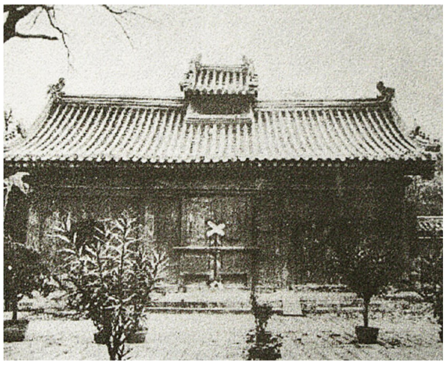


Fig 2.37 A typical Ao with three Jian in Xiannong Altar (source: Jhr mr dr A.J. van Citters) `

Accordingly, " *Jian*" became the next aim of standardization. In the beginning, Zhang Chaorui tried to build up a standard of the volume of *Jian* all over the country, demanding that the minimum storage capacity of a *Jian* should be 24,000 kg (徐 光 启 , 1639). Then the officials of the Qing dynasty accepted the Ming dynasty's tradition and developed this standardization tradition. In the official building code of the Qing dynasty, *Gongchen Zhoufa Zheli*（工程做法则例）[32], there is a particular chapter about the construction of the granary (Fig. 2.38). In this chapter, officials used *Jian* as a standard module of the granary and drafted detailed provisions on the section, number of columns, foundation construction, and numbers of other building components. The size of a *Jian* was defined as 4.16 meters wide and 13.5 meters[33] long in this book (允 礼 , 1734; 梁 思 成 , 2006, p. 92). Meanwhile, in the two existing state granaries of the Ming dynasty: *Ganzhou* granary at Ganshu and *Nanxing* granary at Beijing, the sizes of *Jian* of *Ganzhou* granary is 3.6 meters wide and 12.3 meters long; while in the *Nanxing* granary, a *Jian* is 4.6 meters wide and 17.9 meters long (张 玉 林， 黄 杰 , 2013, p. 308; 杨 波 , 2013, p. 59). When comparing the standard size of Jian of the Qing dynasty with the two examples from the Ming dynasty, they are similar.

32. Gongchen Zhoufa Zheli（工程做法则例）was a Chinese official building code which was promulgated in 1734.

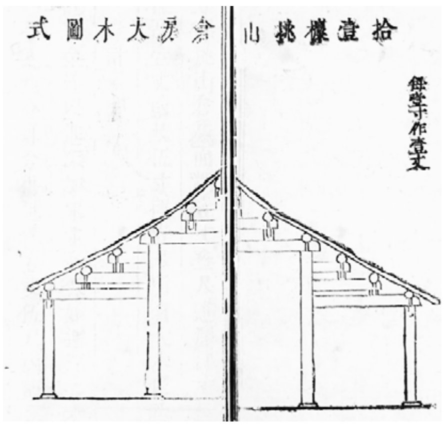


Fig 2.38 A section of a storage building in *Gongchen Zhoufa Zheli,*the official building code of the Qing dynasty.

The *Ganzhou* granary located in Zhangye, Ganshu, provides us with a typical example of state granary of the Ming–Qing dynasty. It used to consist of 22 *Ao*. Nine remain. According to the remaining *Ao*, we see that all ao of this granary were built in the same form. Each ao comprises five *Jian*. A typical *Ao* was a rammed-earth building with an inner wooden frame, built on a 1-meter-high rammed-earth foundation. The floor of the *Ao* is a wooden floor elevated 1 meter above the foundation. A series of small openings is distributed regularly along the upper part of the frontage and back walls of the *Ao* (张玉林，黄杰 , 2013, p. 308).

Comparison of state granaries from the Ming–Qing dynasty with those of the previous dynasty reveals an obvious difference: the size of the single storage building of the Ming–Qing dynasty was mostly much smaller than that of the Song dynasty. An *Ao* of *Ganzhou* granary of the Ming dynasty was 17.8 meters long and 11.3 meters wide, while the storage building of *Zhenjiang* granary of the Song dynasty was originally 110 meters long and 29.5 meters wide. One possible explanation is that this change took place due to building standardization for granaries. Aiming to implement the same standards in local and central state granaries, the scale of an *Ao* should fit both the minimum capacity requirement of the granary of the smallest town and the maximum capacity requirement of the granary of the capital. The maximum capacity requirement of the granary of the capital was not a problem. By increasing the number of *Ao*, the total capacity of a granary could easily be increased to multiples of a single *Ao*'s capacity. The problem is how to deal with the minimum capacity requirement of the smallest town[34]. It seems possible that officials then decided to set the capacity of the smallest type of standard *Ao* to be the minimum capacity requirement of the smallest town. This solution can avoid further spatial separation. Thereby, the capacity of the smallest standard *Ao* is comparatively small, as well as the size of the single storage building. Due to the small storage buildings, the number of *Ao* in the large granary increased correspondingly. We have reports that one of the main capital granaries consisted of 236 *Ao* in the mid-Ming dynasty (大明会典 , 1587).

34. According to the regulation of state granary, the total amount of stored grain of an ordinary small town should reach 600,000 kg (徐光启 , 1639). And this amount of grain was asked to be stored in four granaries located in four different places of the town. The capacity of each granary should be around 150,000 kg (徐光启 , 1639). A standard '*ao*' with 3 '*Jian*', which was the smallest 'ao' type, could exactly meet this requirement, according to the opinion of the officials (徐光启 , 1639).

2.8.1.2 Building construction regulations

According to the literature and given the remaining granaries, the major construction characteristics of the state granaries changed very little during the Ming–Qing dynasty. Most of the state granaries of the Ming–Qing dynasty seem to be built in a similar way: rammed-earth walls or rammed-earth walls covered with bricks, elevated wooden floors, wooden roof structure, and tiled roof. This similarity is likely to be the result of complying with the unified building regulation of the state granary. However, some minor construction details could be varied according to practical needs, such as roof monitors. The *Gongchen zuofa zeli* (工程做法则例) suggested that each state granary should be built with monitors on the roof ridges for ventilation, while some granaries like Ganzhou granary ignored this requirement in practice.

In a comparison of the building regulations related to the granary between the Ming–Qing dynasty[35] and the Tang–Song dynasty, it is obvious that the building regulations of the Ming–Qing dynasty emphasized the importance of moisture-proofing. Certain building construction details and management measures recorded during that period concern how to act against moisture. The officials at that time already realized that moisture came not only from environment but also from the respiration processes of the stored grain. In order to promote the dryness of state granaries, they tried to set a series of unified regulations in building construction projects:

i. Site selection and foundation. As with the Tang–Song dynasty, the site of the granary should be high. Zhang Chaorui suggested that drains should be dug beside the storage building to keep the site dry（允 礼，1734). The forecourt of the storage buildings should be paved with stone slabs, aiming to facilitate the drying work. The foundation of the storage building should be made with rammed earth[36]. The interior floor should be firstly paved with bricks, and then stone bases which support the upper floor beams for the upper wooden floors. The wooden floors were asked to be made of thick pine or fir wooden planks. Finally, the finishing layer of the floors should be bamboo mats. As the grain would be stacked above the floor directly; the bamboo mats were used to prevent the leakage of stored grain.

ii. The exterior wall. According to *Qingding shoushi Tongkao*(钦 定授时通考), the exterior walls of the storage buildings should be built on stone bases to prevent the absorption of moisture. Furthermore, in order to prevent the stored cereals from rotting due to increased humidity, especially the grain stored next to the brick walls, Zhang Chaorui suggested that a wooden wall should be added inside the storage room to create interval space between the brick wall and the stored grain. This method was originally to promote ventilation inside the storage room.

iii. Roofing. To ensure the waterproofness of the roof, it was suggested that the covering of the roof should consist of several layers from the inside out: wooden planks, bamboo mats, a mixture of earth and lime, and tiles（允 礼，1734). Lv Kun further suggested that the roof tiles of the storage buildings should be soaked in alum solution before use, aiming to promote waterproofing（允礼，1734).

In addition to these detailed building regulations, the *Qingding shoushi Tongkao* provided another method for granaries in humid regions. It proposed that managers can leave one room free in one ao when storing grain in the granaries of humid regions. This empty room allowed that stored grain of other Jian can be transferred into

35. The building regulations of Ming-Qing dynasty are referred to the building regulation related to granary construction in Daming huidian (1587),Gongchen Zhuofa Zeli(1734),Cang ao yi(1639), Qingding shoushi Tongkao (1742)

36. The rammed earth foundations of the existing storage buildings of Ming-Qing dynasty were mostly found to be the rammed Sanhetu, a special mixture of earth and lime.

the free room in turns during rainy seasons. Thereby the moisture and heat produced by stacked grain could dissipate.

2.8.1.3 Discussion

The standardization process on building state granaries in the Ming–Qing dynasty led to the patterns of granaries that tended to be unified all over the country. Although some construction details varied according to different regions, the main characteristics of these granaries were much the same, according to the remaining granaries of the Ming–Qing dynasty. In comparison with Tang–Song period, the officials of Tang–Song period emphasized the importance of applying different types of granaries in North China and South China: pits were suggested to be used in North China, while the elevated floor granaries were suggested to be used in South China.

Obviously, the standardization of the construction can effectively speed up the progress of the project and allows for easier monitoring of budgets. Budgeting for against building speculation was quite important for a centralized state. However, the unified building construction method could not adapt well to the varying requirements for storing grain under the varying climatic conditions throughout the entire empire.

2.8.2 *Yi Cang* (义仓)

Due to the change of the agriculture tax since the late-Ming dynasty[37], the amount of stored grain in state granaries continually declined. In the late-Qing dynasty, the government realized that the small amount of stored grain in town granaries was insufficient when famine happened. Meanwhile, many state granaries were also damaged due to the fact that they were not use long periods. However, the government was not willing to pay extra to increase local grain reserves and to build new state granaries. Instead, the government tried to persuade local rich families to donate the construction of public granaries and the grain reserves. These public granaries were called as *Yi Cang.* A great number of *Yi Cang* were built in the late-Qing dynasty.

Compared to the state granary, the construction of *Yi Cang* was mostly more flexible, from the layout to the construction details. In *Fentu Yicang of Shangxi,* North China, a series of brick vaults were applied in the storage buildings, instead of the common wooden roof structure (Fig. 2.39). In Laoguan of Sichuan, South China, the wooden planks were applied as the exterior walls in local granaries (Fig. 2. 40). This measure did not follow the regulation of the state granary but followed the local building tradition.

37. The primary agriculture tax was levied in kind. It means that farmers paid grain to the town granaries of local government. Part of this tax grain would be stored in the town granaries as grain reserves in order to be stored for a case of famine. However, the agriculture tax was changed in Mid-Ming dynasty. Part of the agricultural tax can be paid in silver. This policy was carried on in Mid Qing dynasty.

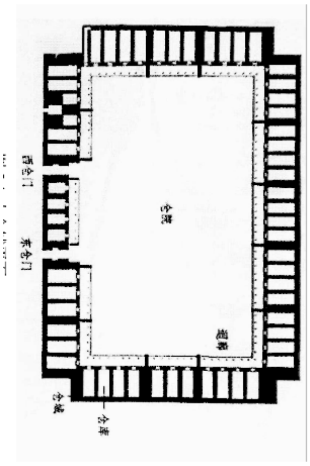


Fig 2.39 The plan of Fentu Yicang, Weinan, Shangxi. (source: 杨 宇 峤 , 2003,Fig 5.4)

Fig 2.40 A granary in Laoguan, Sichuan

2.8.3 Private granaries

Similar to the state granaries, the building technology of private granaries was supposed to be without any important development during the Ming–Qing dynasty. Most of the paintings with an agricultural motif in this period that copied the *Genzhi tu* of the Yuan dynasty (王加华, 2018, p. 91). Considering that many remaining traditional granaries of Han villages are similar to those types described in Nongshu of Yuan dynasty, we can suppose that the building forms of granaries also did not change too much in the Ming–Qing dynasty.

2.9 The Republic of China period (1912–1949)

In this period, wars occurred frequently in most regions of China. During the Second World War, the Japanese army occupied the major area of Eastern China, and the Chinese central government was forced to move to Chongqing, Southwestern China. To sustain the Chinese army's food, the central government called for a raise in the agriculture tax rate to gain more rice from the countryside. In order to store these grains, more granaries were needed. Because of the shortage of funds during the wartime, many temples and ancestor halls were transferred into the state granaries. This situation was particularly common in Guizhou and Sichuan. An example of such is Yuwang Temple. Shown in picture Fig. 2.41, builders kept the main frameworks and roof of the temple and removed all original partitions. Then they put wooden planks between pillars to form storage rooms. Elevated wooden floors were added in these storage

Fig. 2.41 Yuwang Gong Granary, Shiqian, Guizhou (source: 沈健，2009，p28)

rooms.

2.10 The People's Republic of China (1949–present)

2.10.1 State granary

At the beginning of the 1950s, the government decided to build new modern state granaries. They imported modern building construction technology from Soviet Union and promoted it all over the country, including in remote mountainous areas such as Yunnan province (云南省麻栗坡县地方志编纂委员, 2000, p. 526). The new modern granary form was named "Sovietize warehouse". One main advanced feature of this type of granary was that it allowed for mechanized operation, which was urgently wanted by the new government (粮食大辞典编辑委员会, 2009, p. 491). As in other areas, the modernization of the building technology for granaries was seen as an important part of promoting the modernization of the whole country. However, due to the shortage of steel, conveyor belts and motor machines were absent in most of these Sovietize warehouses. These machines would have been the key to mechanized operation in granaries. On the contrary, people soon found many disadvantages of this type of granary. Among them, a most important disadvantage is that this kind of granary cannot adapt to the humid weather of South China.

The modernization of the building technology of the granary continued in the following decades. Most of the state granaries are built with modern materials such as concrete and steel nowadays. Only in some remote areas are traditional granaries built in style of the late-Qing dynasty or the Republic of China period still in use, such as in Gangzhou granary and Laoguang granary.

2.10.2 Community granary（公社粮仓）

Since 1958, the People's Commune act（人 民 公 社）[39] became an official state policy and was distributed to the vast countryside areas. Only some remote minority villages were exempt from this policy, such as Wa villages in western Yunnan. Under this policy, the original relation of private ownership in the village was disintegrated. A village was divided into several production brigades, which became the basic units of the People's Commune. Generally speaking, an ordinary production brigade could consist of 10 to 30 families. All fields of the village were repartitioned and allocated to several production brigades. Instead of their former private field, the members of one production brigade were asked to work together on the fields of the production brigade. The major part of the harvest of the production brigade would also be shared by all members. Members had to obtain their ration of grain regularly from the community granary in exchange for vouchers.

39. The people's commune（人民公社）was the highest of three administrative levels in rural areas of the People's Republic of China during the period from 1958 to 1983 before they were replaced by townships. The communes had governmental, political, and economic functions during the Cultural Revolution. The people's commune was commonly known for the collective activities within them, including labor and meal preparation.

Each production brigade owned their own community granary for storing the harvest of the production brigade. Thus, the capacity of the community granary was generally several times larger than that of an ordinary private granary. Compared to the comparatively eaual state granaries, community granaries were built by local carpenters who executed regional building technologies. According to my fieldwork, it can be shown that local carpenters generally chose two different construction strategies to erect the granaries larger than the usual size.

(1) Building a series of traditional granaries of regular size and

Fig 2.42 A community granary located in a former ancestor hall, Gongchuang, Sanming, Fujian.

putting them together in an enclosed place. One is the community granary of Gongchuang, mid-Fujian. Shown in image Fig. 2.42, local people built several storage cabinets in their usual way and put them in the ancestor hall of the village. However, some construction details of these storage cabinets were simplified, due to the shortage of material and time.

2) Building a huge single granary. Such granaries remain in the Dong villages of Guizhou. The community granary of Qingzhai is an example (Fig. 2.43). The size of the granary was 10 times that of the local ordinary granary. Thus, local carpenters needed to apply new methods to build it (for further, see Section 4.3.3.1).

In some remote minority areas, local villagers did not fully implement the People's Commune policy. They insisted upon keeping their own private granaries. On the other hand, they also believed that they needed to express respect for this new policy as a gesture of obedience. Thus, they adopted an approach of compromise. They erected a community granary in the village as the symbol of the People's Commune, but the volume of this community granary was only slightly larger than that of the local ordinary granary. Examples of these granaries can still be seen in the Pulang village Wenji, Yunnan, and the Yao Village Dongmeng, Guizhou. In order to differentiate such community granaries from ordinary granaries, some builders would add more ornaments and use better materials in the buildings. An example of such a granary is the community granary of Dongmeng, shown in picture Fig. 2.44. It owns more complex braces and with stone mouse guards.

2.10.3 Private granary

Thus, very few private granaries were built during the 1950s–1970s. After the People's Commune system collapsed in 1978, farmers regained ownership of their lands, distributed according to a determined key. The area of a farmer family's field is allocated by the number of their family members. They began to use private granaries to store their harvests again.

In some areas, especially in remote mountainous areas with poor traffic conditions, some farmers continued to use their old granaries, which might have been built in the late-19th century or the early-20th century. Meanwhile, some farmers built new granaries in their local traditional way. These granaries comprise most of the study cases in this dissertation.

However, in the vast plain areas occupied by the Han, many ancient private granaries were dismantled during the Cultural Revolution. The introduction of the modern materials, including concrete,

plastic, and steel, and the shortage of timber resources, caused the disappearance of the construction of traditional granaries in these areas after the 1980s. According to a series of studies on the storage methods of farmer families in the North China Plain, the middle and lower reaches of the Yangtze River, PP woven bags, clay pots, and concrete pools were mostly used to store grain (王若兰 , 2006, p. 50) (朱邦雄 , 2006, p. 38). These methods were considered to be rather inefficient and poor, as they cause a great amount of grain loss during storage. Next, the central government launched a program to promote 11 types of standard small granaries to the farmers. One type of small granaries stand out among these 11. It has cylindrical shape and is made of steel. It is widely promoted in South China, including the remote mountainous areas (Fig. 2.45). The promotion of this type of granaries mainly started in 2011. Farmers can get this type of steel granary at quite a low price, or even for free. Accordingly, the provision of this option accelerated the demise of traditional granary construction technology even in remote mountainous areas.

Fig 2.43 A large community granary, Qingzai, Liping,Guizhou.

3. Wooden Granaries in Fujian

3.1 Background

3.1.1 Environmental and societal factors

Fujian is a province located on the Southeast coast of China. It was considered as a remote border region of the empire until the Tang dynasty. Since the Song dynasty, a huge influx of Han immigrants gradually changed most areas of this region into Han settlements. Consequently, it then stood directly under the control of the central government and joined the trade network of the whole empire (Fig. 3.1).

The local warm and humid subtropical climate is especially favourable for rice cultivation. The main rice species planted here is normal rice[1], which generally yields a higher quantity than does sticky rice or highland rice. It is recorded that the normal rice yield of Fujian already reached 319 kg/*Mu* in the Qing dynasty, the highest rice yield in China up to that time (史志宏, 2012, p. 56). Before 1960, most areas of Fujian planted single-season rice. In the 1960–1980s, double-harvest rice was promoted among the whole province as mandatory; thus, the average rice yield of Fujian in one year increased to 702 kg/*Mu* (柯文涛, 1988, p. 49). Contrary to the high rice yield, the per capita arable irrigated land of Fujian is much lower than the Chinese average. In addition, the frequent climate disasters of this region, including floods and droughts, always affect farmers' harvests.

Most parts of Fujian are mountainous and hilly areas, while there are some small pieces of fertile plains along the coast. There are two main types of arable land in Fujian: irrigated fields and dry lands. The former is mostly for planting rice, while the latter is for sweet potato, peanut and so on. In general, the arable lands for rice cultivation are fairly scarce in Fujian.

On the other hand, the local subtropical mountainous and hilly areas provide an ideal environment for planting Chinese fir, tea, and varieties of fruits. Most mountainous areas are covered with commercial forests, most of which are feature Chinese fir trees and pine trees (*Pinus massoniana Lamb*, 馬尾松). Due to the abundant forest reserves, forestry used to be one of the local pillar industries

1. Normal rice here refers to either Indica Rice(籼稻，Latin: *Oryza sativa* subsp. *Indica*) or Japonica Rice (粳 稻，Latin: *O. sativa* subsp. *Japonica*).They are two major varieties of rice planting in China.

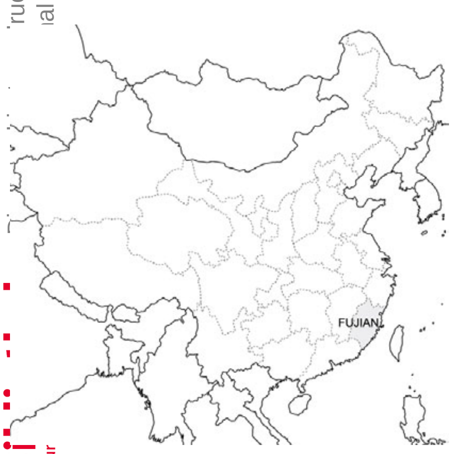


Fig 3.1 Location of Fujian province.

and plays an important role in supplying the local farmer families' income.

3.1.2 Staple and food shortage

Rice is the main staple of local Han people in Fujian. However, rice shortages were one of the main threats for local inhabitants in the last hundreds of years. Since the Ming dynasty, the sustained population growth in Fujian led to reduction of per capita arable land[2]. In the same period, the development of tobacco and sugarcane cultivation, imported in Fujian from abroad, changed more and more rice fields into tobacco or sugarcane plantations due to the high profits of these other crops (福建省地方志编纂委员会, 1993, p. 12). Meanwhile, frequent climate disasters usually decreased the total rice output. In the early Qing dynasty, an area of around 25% of Fujian faced rice shortages (徐晓望, 1992, p. 40). Hence, the field output of the ordinary farmer families of those areas was not even enough to feed a family for one year.

2. According to a Fujian government statistical report for 2005, the per capita arable irrigated land of Fujian is only 0.48 *Mu* per person in 2005 (福建省统计局, 2005).

Local farmers had to look for diverse measures to ensure their food supply. There were three major measures mostly applied by the local farmers among the countryside of Fujian:

i. Improving the agricultural technology: Aiming at adapting the various terrains of Fujian and different types of soils, a variety of subspecies of rice were bred out. In the mountainous regions, farmers mostly cultivate a species of rice called "late rice" (晚稻) in the high terraced fields, and cultivate "early rice" (早稻) in the valley plains fields with lower altitudes (韩茂莉, 2012, p. 986). The former species could be sowed from mid-June to August and harvested in the mid-October, while the latter species could be sowed from mid-March and harvested in mid-July (福建省福安市地方志编纂委员会, 1999, p.381).

The growth period of rice lasts three to six months. To make full use of the field, farmers developed the double-harvest rice rotation technique in the fertile plain areas. After harvesting, early rice could be followed by late rice. With this technique, the yield of a rice field can be nearly doubled. However, this technique can be only applied in fertile fields, as it will exhaust a field quickly. It also required double the labour to work the field.

ii. Making full use of drought lands and sandy lands: In order to solve the arable field shortage, farmers succeeded in importing a new crop species: sweet potato in the mid-16th century (韩茂莉, 2012, p. 989). Sweet potato could be harvested several times in one year and could be cultivated in the barren lands where rice could not grow. Other types of secondary crops, such as peanut and bean, were widely planted in the dry land or in the rice paddy field after the rice harvest. All of those crops became important supplies to ease the food shortage problem.

iii. Importing rice from abroad: Besides other crops such as sweet potato, many local farmer families also relied on commercial rice from abroad to overcome the rice shortage situation in the past. Commercial rice was mostly shipped into villages on rivers. Thus, plenty of marketing points were developed along the transportation routes, indirectly contributing to the affluence of some towns and villages with ports. Farmers could sell tea, timbers, mushrooms, and other forest products in the markets close to their villages. These markets offered convenience for locals to buy commercial rice.

As a result, a local Fujian farmer family rarely stored rice in larger quality than they could consume within a year, partly due to the shortage of arable land and partly due to rice markets in neighbourhood. In this case, the capacity of local farmer families' granaries could be smaller, compared to those of other rice producing areas.

Since the late 1970s, the promotion of high-yielding hybrid rice largely alleviated rice shortage problems among the people of the countryside. Meanwhile, the decrease of the population of villages in the subsequent decades also helped to alleviate this problem in some villages .

3.1.3 Rice harvest process in Han villages

Traditionally, before the 1960s, the whole harvest process of rice was done manually in the countryside. This was fairly labour-intensive work. In Han villages, it usually required all family members to participate. According to the amount of labour force and the scale of the rice field, the farmer family's harvest process could last several days or even weeks. In the areas where farmers planted double-harvest rice or different types of rice, they usually harvested rice twice or more each year (Fig. 3.2):

i. Reaping: Reaping was to start as soon as the rice matured; otherwise, the rice ears fall to the ground. This would cause a loss.

Fig 3.2 The traditional harvest process in Han villages.

Fig 3.3 Farmers usually threshed rice in their field before transportation in the past.(source: 陈志华 , 2007, p. 19)

The rice maturing dates differ according to the planting region and its rice species. Most of the early rice in Fujian would be mature in mid-July, while the later rice would be mature in mid-October.

ii. Threshing: In local Han villages, rice reaping was generally accompanied and followed by threshing work. Threshing paddy rice in the field aims at reducing the weight of rice, which had to be transported on foot in the past. As the distance between the field and the village usually is quite large in Fujian, carrying only kernels back home can significantly facilitate rice transportation. During the threshing process, people usually worked in groups: some were responsible for cutting rice with sickles, while some were responsible for threshing it in the paddy field with special agricultural implements: threshing baskets (打 谷 桶)[3] (Fig. 3.3). Concerning normal rice, the kernels stick significantly less to the straws than is the case with sticky rice. Therefore normal rice can more easily be threshed on the field. Thus the manual threshing work was less labour-intensive in areas of normal rice cultivation than in areas of sticky rice cultivation.

3. In the 1950s, the threshing machine was introduced to the villages of Fujian and then widely applied. This effectively speeds up the threshing process.

iii. Transportation: Due to lack of large animals in the villages of Fujian in the past, people traditionally relied on transportation by foot walking to transport rice from the field to the village[4]. A pair of bamboo baskets and a shoulder pole were used as the main tools for the transportation (Fig. 3.4). The conventional capacity of a bamboo basket is 40 kg. Hence, each man could carry 80 kg back to the village in one round. A round trip could take 1–4 hours, depending on the distance between the field and the village. Consequently, the rice transportation work usually lasted several days.

4. Tractors were introduced into the countryside of Fujian in the 1970s, and then applied for rice transportation in some areas. Now motorbikes are also widly used for rice transportation in mountainous areas.

iv. Drying: Before being stored, rice has to be dried to a certain degree if it is intended to be preserved. Sunshine and wind were the main supporting attributes in the drying process in Han villages. Whatever drying method is applied, a clean plain area is necessary. Cereals should be spread out on the plain in a thin layer, to facilitate and accelerate the drying process (Fig. 3.5). Under ideal conditions,

Fig 3.4 Bamboo baskets for carrying rice in the past.

Fig 3.5 bamboo mats for drying rice.

Fig 3.6 Temporary bamboo platforms for drying rice in paddy fields,Pingnan, Fujian. (source: 屏南文体局)

rice could dry in two to three days on sunny days. However, as the plain drying areas were mostly quite limited in the villages, the harvested rice was dried in turns. In this case, the whole drying process for all output from one family's field usually lasted longer than a week. Rain could disturb the open-air drying process, lengthening the drying process. As the rice harvest time of many areas meets the rainy season in Fujian, the rice-drying process there caused many problems.

According to the long duration required to dry the rice, Han farmers preferred to make their rice-drying locations close to their dwellings. They could thus always keep an eye on those places as a as a security measure while doing household work. In Fujian, some farmers built flat drying squares in front of their dwellings; some even used the inner courtyards for drying, which is safer. In some densely populated villages, farmers would also build temporary bamboo platforms next to their houses or in the fields on the borders of the village (Fig3.6). In the northern coast region of Fujian, farmers even adapted the ceiling of their living spaces as drying places, then covered this space hwith huge roofs.

v. Winnowing: Winnowing is the last step before rice is stored. The Han people generally used wooden winnowing machines for winnowing in the past. The winnowing process was usually carried out in the drying place or in an area next to it.

The rice was generally stored in the granaries still covered with rice hulls. Rice hulls must be removed with the hulling machine before cooking. Farmers built public water rice hullers along the rivers in some villages, and some farmer families had a private rice huller in their dwellings. Rice without hulls was stored in small glazed pottery, the capacity of which could provide one family's food for several days. For convenient access, the glazed pottery was located directly in the kitchen. The glazed pottery offered a safe and fireproof shell for the rice storage.

3.1.4 Forestry and carpentry technology of Han people in Fujian

3.1.4.1 Forestry resources

Chinese fir used to be the main construction material for local construction. Chinese fir forests in Fujian are all commercial forests. According to historical record (福建省地方志编纂委员会, 1996, p. 166), the optimal rotation age of fir forests in Fujian used to be 30–35 years. Due to the abundant forest resources of previous times, most of the construction timbers applied in local buildings were timbers with larger diameters and better quality, as compared to other surrounding regions. However, due to the promotion of the People's Commune, most of the forest lands came to belong to the country and "commune". In the 1960s, the government executed a law that the optimal rotation age of Chinese fir forests should be no less than 20 years. Accordingly, most of the fir trees were felled at the age of 20 years. As a result, the construction timbers felled after the 1960s were mostly shorter and of smaller diameter than they were before this time .

3.1.4.2 Carpentry tools

Han carpenters generally use diverse carpentry tools in construction projects. Many of them[5] were made by carpenters themselves in the past. In Fujian, most Han carpenters used nearly the same types of carpentry tools. Experienced carpenters usually owned more carpentry tools than did apprentices. Thus, they also had the ability to do more precise work. The specific forms of some certain types of carpentry tools also differed from place to place, and unique carpentry tools were invented for special details, used only in a certain area. In the 1960s, mechanical saws were introduced in this area, however, which replaced the crosscut saw as the main tool for logging and cutting planks. In addition, electronic levels have been widely used in traditional buildings in Fujian in the past 10 years.

5. The iron blades or steel blades of these tools were mostly produced by the blacksmith.

Fig 3.7 Traditional carpentry tools of a local carpenter in Beichun, Fujian.

According to the function of carpentry tools, the traditional carpentry tools[6] of Fujian can be divided into the following five major types (Fig3.07).

6. Here I list the carpentry tools of ordinary carpenters from Mid-Fujian and Easten-Fujian. This part is mainly based on my first-hand investigation and the book' Studies on the craftsmanship of traditional Chinese carpentry in Fujian region'.

i. Cutting tools

Axe（斧）: There are mainly two sizes of axe used in construction work: a large axe and a small axe. Some carpenters have an additional mid-size axe. They are mainly used for cutting woods into intended lengths or shapes.

Frame saw（框锯）: Some carpenters own two kinds of frame saws: *Zhiju*（直锯）and *Henju*（横锯）(张玉瑜, 2010, p. 123). *Changju* is used for cutting wood along the grain direction, while *Jieju* is used for cutting wood in direction perpendicular to the grain direction. The former can be used for cutting fork ends of pillars.

ii. Smoothing and flatting tools

Plane（铇）: A plane is used for creating flatten and smooth wooden surface. Nearly every Han carpenter owns more than one wooden plane for flatting. For example, an ordinary carpenter in Beichun village of northern Fujian owns three planes: a small plane, mid-size plane, and a long plane（长铇）(Fig3.8). The long plane can be used to create a fairly fine and smooth plan of a wooden component. As mentioned in Section 2.7, the application of the plane could be related to the innovation of a special wall construction of granaries, which can be found in Zhongshan village, Mid-Fujian.

Drawknife（刮 刀）: This tool is supposed to be introduced from abroad in the later 19^{th} century or early 20^{th} century. It is a common carpentry tool used for debarking logs and for rough flatting work.

Spokeshave（鸟 铇, 弯 铇）: This tool is also used for shaping and smoothing curved wood. The spokeshave found in Beichun village has an industrialized metal body. We have not yet found any record of whether such a carpentry tool was introduced from outside, but

Rudolf P. Hommel has recorded that it had been used in China as early as the 1930s.

iii. Tools for digging and shaping

Chisel（凿）: A chisel is the most common and effective tool for making wooden joints in construction projects. It is also used in carving patterns on wood. For different purposes, the shapes of the blades of chisels vary. An ordinary carpenter of Fujian usually owns two types of chisels: chisels for digging mortises and shaping tenons and chisels for cutting grooves. The latter are named as *Chang*（铲）. They have wide and thinner blades. There is a special type of chisels specialized for making sockets of dovetail joints（张玉瑜, 2010, p. 121). This tool can be related to the construction detail of granaries in Chang Lingmao (for further, see Section 3.3.2.1).

Rasp（锉）: A rasp can be used for shaping small wooden components.

Joinery plane and molding plane（槽铇与线脚铇）: The forms of these tools vary according to the requirements.

Drill（钻）: Only some carpenters use drills. There are two major types of traditional drills used in Fujian: a small hand drill and a bow drill. In Northern and Mid-Fujian, carpenters specialize in combining several thinner components into a large one by using bamboo dowels in-between . For cutting sockets for installing dowels, they usually used a special type of drills: *Gezhuan*（格钻）.

iv. Measurement and drawing tools

Chalk line（墨斗）: This tool is used for drawing long and straight ink lines on wooden components.

Square（曲尺）: This is one of the most important measurement tools for carpenters. It usually comes in two sizes in Fujian. The long side of the larger one is around 66 cm (2 *chi*[7]), and that of the smaller one is around 33 cm (1 *chi*). Squares are usually used for checking mortise and tenons, and some small components. In southern Fujian, carpenters have started to use tape measures (张玉瑜, 2010, p. 117).

Gaoci（篙 尺）: Gaoci is a long and narrow wooden board with marks. It is mainly used to record and express the section design for planned buildings . The marks of the Gaoci generally express varying intended heights of pillars, positions of beams and mortises, and other important section information（张玉瑜, 2010, p. 77). Therefore, each Gaoci actually corresponds to a specific building. The length of Gaoci is usually 10 cm longer than the longest mid-pillars than

7. *Chi*（尺）: The chi is a traditional Chinese unit of length. Chi has been defined as exactly 1/3 of a meter in China since 1984.

in the building under construction. To measure the building plan, carpenters in some areas use a kind of shorter wooden stick with marks, apart from Gaoci.

Marking gauge (勒子): This type of tools is used for scribing a line parallel to a reference edge or surface.

v. Tools for application of force

Hammer (锤): Not every carpenter has an iron hammer; some carpenters use only the back of an axe for a pounding tool . They are usually used with chisels for cutting or digging (张玉瑜, 2010, p. 127).

In summary, an experienced Han carpenter traditionally worked with a great number of carpentry tools. Some of his carpentry tools had been created only to deal with certain specific details, however. These carpentry tools ensure that Han carpenters owned the ability to make very fine woodworks. It would be easier for them to achieve good sealability in a granary.

3.1.4.3 Building process

The building process required several steps:

i. Logging: Traditionally, Chinese fir trees were mostly felled by professional fellers during the winter time from mid-October to mid-March[8]. One reason is that local carpenters believed that timbers felled in that period are of better quality. Another reason is that the breeding of Chinese fir trees used to rely on the remaining root parts for germinating. Felling a Chinese fir tree in the winter time would allow the remaining root parts to germinate immediately in the following spring period (福建省地方志编纂委员会, 1996, p. 168).

ii. Drying: Traditionally, after the trees were felled, they would be firstly left on the mountains for 10–30 days before the initial pruning process. Workers would then come to prune the branches off, trim the cuts on the trunks, and peel off the bark .

iii. Transportation: Rafting on rivers was the most common method of long-distance log transportation in Fujian in the past. This cheap and convenient transportation allows villages situated along the coast and lacking their own forest resources easily to import large timbers from the mountainous areas. After the 1970s, trucks were introduced to replace shipping transport. Due to the limitation of transportation facilities, it is recorded that the length of commercial timber usually did not exceed 10 meters (福建省地方志编纂委员会, 1996, p. 182).

8. However, there was also another uncommon tree felling period in Fujian in the past. In some areas, fellers sometimes also cut down trees in spring. The tree's bark can easily be peeled off the trunk in large pieces by the ripe knife when the tree is full of sap in spring. As fir barks were recognized as cheap and easy alternatives of roof tiles in some remote mountainous villages, getting large pieces of barks became one main determining consideration for the felling date. w

iv. Processing: When logs arrived at the building site in a village, rough modification work would begin immediately. The experienced carpenters came to check the logs. Then they decided the future function of each log, according to the quality and the length of them. The timbers for beams and pillars would be roughly trimmed into their intended forms by axe, and the timbers for planks usually were cut by a saw. For such a conversion work, big frame saws were the traditional tool, replaced by the mechanical circular saw in the 1970s. After this rough processing, these timber construction materials would be stored somewhere to allow their drying process to continue. The steps in the final building process, such as digging mortises and trimming timber into intended forms, would not start before the master carpenter was content with timbers' dryness nor before the client successfully collected all necessary building materials.

Generally speaking, due to the abundant forest resources and the relatively mature carpentry techniques, the timbers applied in traditional granaries and dwellings of Fujian are mostly of large diameter and high quality. However, due to a series of forestry policy changes from the 1960s to the 1980s, the general construction timber quality of Fujian dramatically decreased, and the average diameter of the construction timbers also decreased. This change affected the granary building craft of some regions.

3.2. Brief introduction about granaries in Han villages of Fujian

Generally speaking, due to the limited rice output, the rice storage amount for general farm families in Fujian was less than that of other areas of South China. Local farmers preferred to erect their small granaries at a place very close to where their rice would dry place and to their dwelling. In mountain villages, where the layouts can be generally unlimited, farmers built free-standing granaries located next to the dwellings and in drying places. Changlingmao is an example of such (discussed later) . In some bigger villages with dense populations, farmers preferred to store rice in their dwellings by installing rice cabinets or storage rooms, such as Zhongshan shown in the following section. In northern Fujian, due to the lack of field for drying places, people even integrated granaries, dryings platform, and residences together into a large building.

The risk of fire is usually the main determining factor keeping the wooden granary far away from the dwelling. Why did Fujian farmers dare to put their granaries next to their dwellings, or even inside the dwellings? One answer is the wide application of diverse fireproof building materials in local dwelling constructions. Those fireproof building materials, such as rammed earth, brick, and wattle and daub efficiently decreased the risk of spreading fire in villages in Fujian. Meanwhile, the convenient rice marketing system also helped farmers to overcome the fear of famine caused by possible fire damage to their granaries.

3.3 Han village: Chang Lingmao

3.3.1 Village, dwellings and granaries

Chang lingmao, a small village with a population of around 400 people, is located in the mountainous area of mid-Fujian (Fig. 3.8; 3.9). A number of valleys are formed by streams in this area, offering precious and limited irrigated fields for rice planting. The village is set in one of those valleys. Aiming to save the land along the valley for planting rice, the whole village was built on the steep slope at the foot of the mountain.

The dwellings are generally arranged along the contour lines following no strict rule. Most of the dwellings own flat forecourts in front of the main buildings, acting as the drying places. The granary and other outbuildings serving different functions are also put located around the drying place for the main house.

Most of the dwellings of this village could be recognized as multi-family houses, shared by two or more families with kinship. This mode of living is similar to that of the Dong people. In a local dwelling, some parts are shared by all family members, such as the ancestor hall, the staircase, and the drying place in front of the house. The remaining parts, like kitchens, bedrooms, toilets, and granaries, are strictly separated. The number of granaries in front of the house usually corresponds to the number of families living in the house.

Fig 3.8 The satellite map of Chang Lingmao village, Sanming, Fujian.

Fig 3.9 Chang Lingmao village.

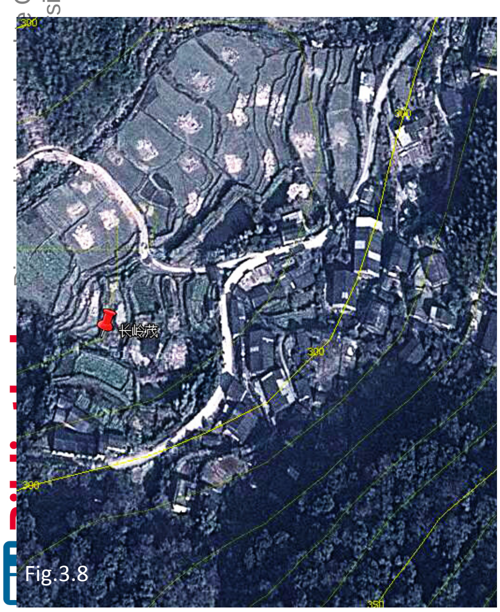


Fig.3.8


Fig.3.9

3.3.2 Granary and its construction

The study case for this section is a typical local granary. It belongs to an ordinary family consisting of four members. Its storage capacity is around 1,500 kg. It is said that this granary is over 100 years old (Fig. 3.10; 3.11).

This granary is a small independent building with a massive wall structure, located on one side of the drying place.
By inserting planks in the grooves of the battens on the wall and the door frame, a half wall with a height of 80 cm can be formed in order to divide the inner space of the granary into two storing areas. This design was supposed to be related to the local rice cultivation tradition. Many local farmer families own rice fields both on higher mountainous slopes and in lower valley areas, due to the topographical restrictions of the area. In higher mountainous slopes, they plant late rice, and in lower valley areas is the early rice. Thus many farmers need to harvest rice twice each year. Aiming to separate the earlier harvest and the later harvest, farmers generally divide the granary into two storing areas (Fig. 3.12).

Similar to the rural granaries of some other cultures, the local granary is not only applied for storing rice, but is intended to shelter some other precious items. In this case, farmers insert a row of shells to store honey and sugar. The gable side eaves extend the granary significantly to allow a protected setting for agricultural implements like a winnowing machine.

3.3.2.1 Structure

The main structure of the granary is comprised of two parts: the inner massive wall structure and the external frames (Fig. 3.13).

The inner massive wall structure also acts as the vertical enclosure of the granary content, bearing the side thrust from the rice stacked inside (Fig. 3.14). The wall structure is assembled of a series of wooden planks with unequal heights (12–23 cm). All these planks are 5-cm thick, which is thicker than wall planks used in granaries with skeleton structures in the same area. Carpenters introduced a special type of sliding dovetail joints at the beams' ends to insert the corner joints of the massive wall structure and lock those planks together.

The sliding dovetail joint is a method of joining two planks at right angles. This construction method can be tracked back to Bronze Ages when the edgings of wells were executed in this kind of log construction. The sliding dovetail applied in local granaries differs slightly from that of the common sliding dovetail joint, as the planks'

Fig 3.10 The selected study case in Chang Lingmao.

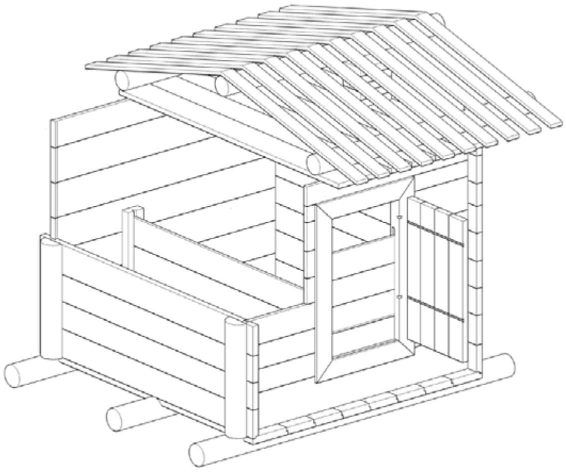


Fig 3.11 Interior spatial division of the granary.

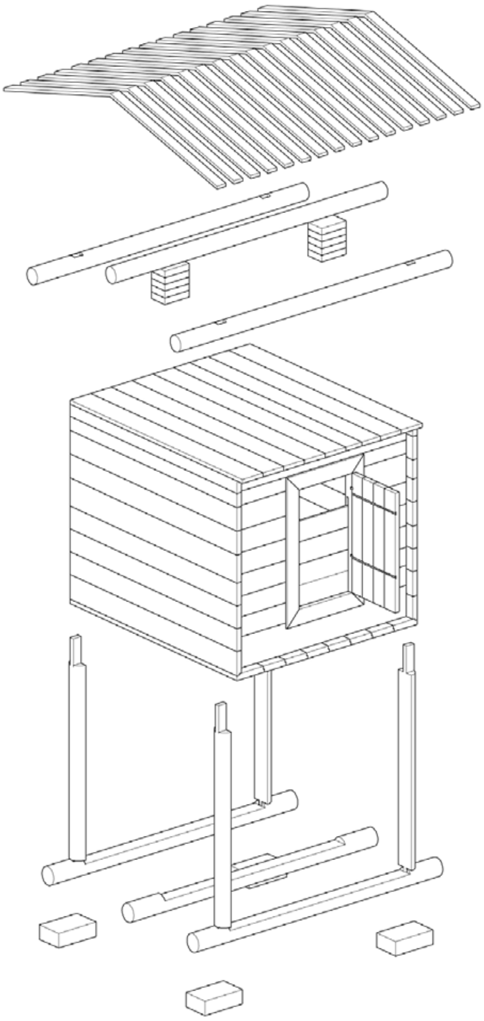


Fig 3.12 Different components of the granary

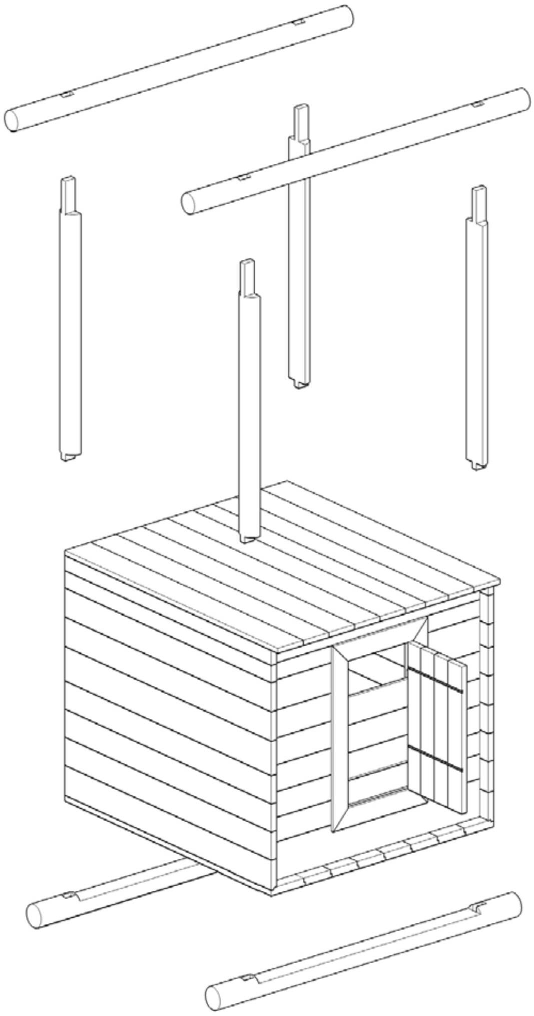


Fig 3.13 The inner massive wall structure and the external frame of the granary.

ends in Changlingmao's granaries are only recessed on one side, creating one-sided dovetails (Fig. 3.15). The characteristic shape of a dovetail with its oblique cheeks is intended to fix the plank pull–resistant to its counterpart. Thus, the strength of this single side dovetail joint should be definitely weaker than that of common one.

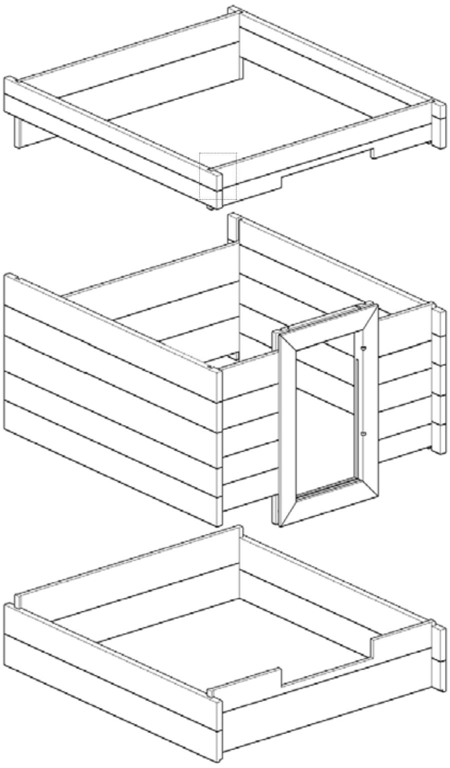
Why did carpenters change the form of the dovetail joints applied in the granaries? I suppose that the intention was to reduce the workload and to avoid too inaccurate work in the production of large wooden members. The common dovetail joint is applied mostly to make smaller wooden items such as doors and flat pot covers. The production of this kind of joints requires more labour input and special tools; thus, it is mostly applied to making small indoor items. Compared to those small indoor items, a granary is quite large. Aiming to reduce the workload required to make the dovetail joint, carpenters simplified the dovetail joints of granaries. At the same time, they aimed to strengthen the whole massive wall structure. According to the granary's size, carpenters added two or three frames to clasp the massive wall structure. Each frame consists of four elements tightly joined, thus resisting the stress exerted by the serial's wright on the sides of the building .

The horizontally stacked boards are of unequal height, most probably to make optimal use of the available material. Carpenters exploited this situation. Ordinary walls of log buildings derive their stability from the interlocking of the beams in the corners. The vertically offset arrangement of the beams meeting at the corners is the essential condition for the mentioned stability. In technically highly developed log constructions erected from equally dimensioned beams carpenters, therefore, the lowest layer started with beams of unequal diameter. In our example, carpenters combined this idea with the fact of having to work with planks of different diameter. Thus, they incorporated an assumed disadvantage into a strong and stable construction by connecting generally two horizontally adjacent planks from one wall side with one beam from the adjacent wall side. Considering the possibility that locals may to rebuild or relocate the granary, carpenters numbered every plank on the plank's inner surface.

When a dovetailed plank's end grain is inserted into the corresponding groove of another plank, the friction resistance increases with the accuracy of the carpenter's work. At the same time, only accurate execution of the joints assured stability. Carpenters found a convincing solution. Instead of cutting parallel sliding dovetails, they tapered them consistent with the corresponding grooves.

The massive wall structure needed to be made by skilled carpenters with special tools. The sliding dovetail joints consist of two parts: dovetail ends and the socket parts grooved accordingly. The socket

Fig 3.16 Wooden wedges were inserted between the floor and the external frame.



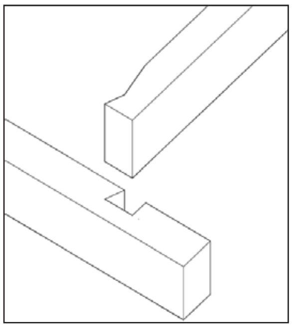


Fig 3.14 Construction detail of the massive wall structure.

Fig 3.15 Detail of the corner joints of the granary.

parts need to be prepared with a back saw and chisels. The finishing has to be done with a special chisel or a router plane, both rarely to be found nowadays.

The external frames bind and tighten the core part of the granary. In our study object, these frames are missing. The main function of the external frames is to fasten the inner massive wall structure, thus preventing the structural crack caused by inner pressure. Additionally, these frames served to support the floor and to fix the ceiling. The external frames usually work in pairs; they are attached outside the core box created by the connected planks where the sliding dovetail joints are worked. Thus, they are intended to strengthen the joints.

Compared to the inner massive wall structure, the construction of external frames is quite rough. It is formed by vertical half logs and horizontal logs. The ends of the vertical half logs are simply shaped into long extended tenons and anchored to the through mortises of the horizontal logs. However, in such a rough framework, local carpenters also considered how to make frames to adapt the height change of the inner box caused by the shrinkage progress. A simple construction detail was invented to allow routine adjustment of the external frame. In the vertical half logs, the upper shoulders of the tenons were intentionally made slightly lower than the height of the inner box at the very beginning. This distance would allow the upper horizontal beams to move downwards together, giving way to the shrinkage process of the inner massive wall structure. By this detail, the external frames can always tightly band the inner box independent of the shrinkage process.

According to my investigation, many external frames in different granaries are damaged or missing, mainly due to the local rainy weather. This situation might be the reason why carpenters executed the external frames in such a rough way. They might have had in mind the necessary need for near-term renewal. After the widely distributed introduction of iron nails since the 1970s, the owners began to replace the former strengthening external frames by hammering nails into the connection joints of the planks.

3.3.2.2 Ceiling and floor

The floor of the granary is comprised of thick wooden planks connected with halved lap joints. The whole floor was laid and fixed in the shallow grooves of the lower beams of the external frames (Fig. 3.16). In this study case, the walls are put directly on the floor. Some additional wooden wedges are found between the floor and the lower beams of some granaries. This can be seen as a simple method to prevent the occurrence of gaps between the floor and walls, due to the shrinkage of wooden planks.In addition, half-lap joints applied between walls and floor also constribute to prevent cereals leaking between gaps in the wall and the floor.

The ceiling is also comprised of thick wooden planks. Different from the floor, these planks are laid side to side. These planks are supported only by walls beneath, without any further support. Thus, the average dimension of these planks was required to be over 5 cm to prevent bending caused by their dead weight. The upper beams of the external frames are applied to anchor the vertical clasping beams and provide a perfect closure of the ceiling. Furthermore, the owners usually put some short logs or bricks on top of the ceiling. This enhanced load was to help to stabilise the ceiling. In addition, this load also contributed to diminishing gaps occurred in the lower massive cabinet during the shrinkage.

3.3.2.3 Roof

The roof of the granary is a separate simple structure. There are three purlins for supporting the rafters and tiles. The ridge purlin is supported by a short pillar above the ceiling, while the other two purlins serve as upper beams of the external frames as well.

Bark roof used to be widely applied to the local outbuildings in the past due to the fact that local remote small villages like Changlingmao usually suffered from a shortage of roof tiles. However, the roof of a granary had to be covered with roof tiles, based on local tradition. The provision of a rainproof cover to protect the grain storage should be undoubted. When an owner could not get enough tiles for his granary in a short time, he would move the main body of the granary inside the house. Then the granary could be temporarily sheltered under the roof of the dwelling until the owner collected enough tiles. The small scale and the massive wall construction of the local granary offered such a possibility that could be moved into the interior space easily. Even today, some granaries without roofs are located inside houses in this area.

3.3.2.4 Door

There are two sizes of openings usually applied in granaries of Changlinmao. One type of opening is around 1.2 meters high, 0.66 m wide, while another smaller one is around 0.8 meters high, 0.6 meters wide (Fig. 3.17). The size of the door of a granary is determined by whether people need to enter the granary, which relates mostly to the scale of the granary.

When the granary is large enough, such as the study case showed

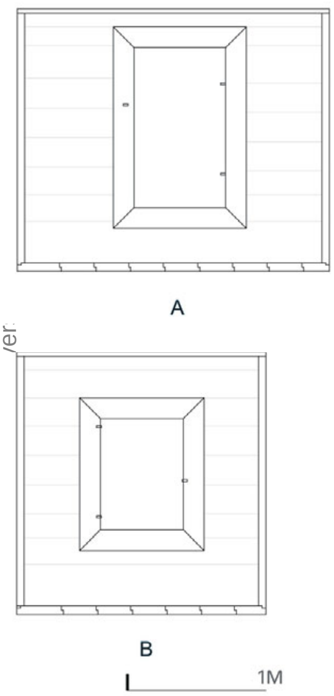


Fig 3.17 Two types of doors applied in granaries of Chang Lingmao.

before, the owner would prefer to divide the inner space into two areas for storing the rice harvested in different seasons separately. In the "early rice" harvest time, the owner can bow to enter into the empty granary for pouring rice into the inner box. In the "late rice" harvest time, they install boards on the door to build a half wall, then pour rice into the outer separated part from the outside.

When the granary is smaller, as in Case B in Fig. 3.17, the owner of the granary usually I did not divide it and would store rice harvested in different seasons together in one space. People do not need to walk into the granary in all cases of small granaries without divisions. We must consider the growing weakening of the massive wall structure related directly to an increase of the wall opening. They can stay just outside and pour the rice into the granary. Consequently, the opening of the small granary can be smaller if people do not need to enter the granary. The door sill of the small granary would be also laid higher accordingly.

The opening of the selected granary used to have two layers of protection, as shown in Fig. 3.12. These layers are a common in this region. The outer layer is a winged door leaf, which protects the opening against too-easy robbery. The second should be an inner movable wall inserted into the grooves of the door frame, for holding the rice stored inside when the heap reaches such a height (I name it the "inner door" wall). This imperative can be implied by grooves on two doorposts (Fig. 3.18). The height of the inner door wall should be around 30 cm lower than the whole height of the opening, allowing people to pour rice into the granary via the gap and also to move the panels out from the groove more easily. With such detailed design, local farmers could enlarge the storage capacity of this granary in good harvest years without building a larger granary. Meanwhile, the maximum height of stacking rice of such a granary can reach higher than would be possible in granaries with a single-layer door.
The construction design of this door is labour intensive, however (Fig. 3.19). The carpenter aims to use fewer components to finish the work. This minimalism leads to an increase in the complexity of the single components of the door.

Fig 3.18 A groove in a door post of the granary.

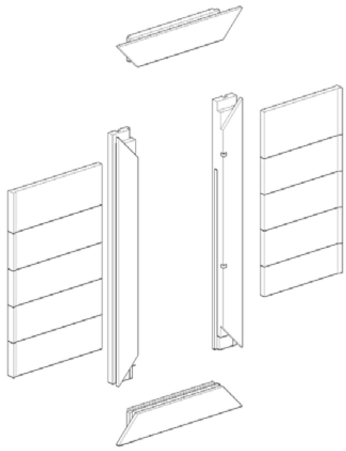


Fig 3.19 Construction detail of the door frame of the granary.

3.3.2.5 Summary

Compared to the wooden framework structure, the wooden massive wall structure owns some advantages for storing cereals:

i. The massive wall structure is more stable and stronger than the framework structure on the same scale.

ii. The sealing problem, the main problem of wooden granaries, could be solved more easily in a massive wall structure than in the framework structure.

Due to the shrinkage process of the wood, gaps would usually occur in the wooden walls. Aiming to prevent the cereal from being lost through wall gaps, carpenters had to find a way to avoid these gaps. In local granaries with massive wall structures, farmers usually laid heavy items, such as bricks or logs, above the ceilings of the granaries. These loads would provide downward pressure on the massive walls beneath. This pressure would help to press the horizontal stacking planks of the walls, thus eliminating increasing gaps between planks.

However, the wooden massive wall structure has to accept certain structural limitations. Granaries with massive walls are generally small. According to my field survey, the long sides of local granaries rarely exceed 3.3 meters. One reason is that the length of the granary is defined by the length of the planks of the wall. The longer the planks, the more easily they would warp. This warping would lead to a deformation of the whole structure. Another reason is that increasing storage volume accompanying increasing scale would produce larger thrust, which might offset or even destroy the fine corner joints. Due to these reasons, the planned size of a granary with massive walls was usually quite limited. When local farmers need a granary to provide more storage volume, they would make two boxes erected in a log-construction style and cover them under one common roof.

Aiming to ensure the strength of the corner joints the thickness of each wall plank is required to exceed over 5 cm. In addition, according to the detailed examination, the wall planks used to build the massive wall structure are mostly boards taken out from the centre of the log, which would bend less and shrink more . Sideboards were cut out of a tree trunk at the left or right side of the centre, bending concave or convex accordingly. Boards cut out centrally shrink to the same extent on their left and right sides. Therefore, these boards stay straight. Such requirements increase the difficulty of timber preparation.

Together with the exhaustion of forest resources since the 1960s, the loss of the mentioned necessary skilful treatment of structural wood elements initiated the phasing out of these buildings.

3.3.3 Variants and changes

3.3.3.1 Variants

In some surrounding villages where dwellings are standing close, carpenters applied the same building craft of the massive wall structure in building indoor grain cabinets. The plan of these indoor grain cabinets is generally smaller than the outdoor granaries using the same building technology (Fig. 3.20). Most of the indoor grain cabinets are built without external frames. Since their storage capacities are generally smaller, the side thrust of stored rice on their walls is reduced as well. Thus, local carpenters relied on dovetail joints alone. They were convinced that this joining method could fix the cabinet without the help of external frames in this case. The omission of external frames also helped to reduce the cabinet's outer circumference, thus saving limited indoor space.

The omission of the external frame led to a change of constructional details in these indoor cabinets as well. The floors of the indoor cabinets are mostly put on inside frames, instead of being fixed on top of the lower beams of the external frames. Compared to the outside construction, the method of fixing the floor inside the frame is a more effective to prevent the cereals' leak from the gaps between the wall and floor. However, this floor construction is not used outside: the protruding tenons of the frame would be in danger of being damaged from exposure to weathering. Damaged tenons would threaten the whole structure. In a word, this kind of construction detail is more suitable for application indoors.

Fig 3.20 A indoor grain cabinet in a nearby village Gongchuang, Sanming, Fujian.

Fig 3.21 A framework granary built during the people's commune period

3.3.3.2 Changes

During the People's Commune period, local carpenters used a more economic construction method in building granaries. Log buildings were replaced by timber frame constructions. Compared to the granaries with massive walls, framework granaries are structurally simpler and could, therefore, be erected more quickly (Fig. 3.21). Considering wall planks applied in ordinary framework granaries, their thickness can be only 3 cm. These planks are significantly thinner than in a massive wall structure. A timber frame granary required less material, in comparison to the massive walls granaries of the same scale. This advantage was significant, considering the shortage of wood supply at that period. Thus, local carpenters built a great number of new granaries with framework structures during the People's Commune period, in order to create more storage spaces for the expected increase of yield. Parallel to this development, the traditional building craft of the massive walls structure started to vanish. Meanwhile, local farmers realize that massive walls granaries are actually more stable and stronger than the framework granaries. Since they experienced that some framework granaries would begin to tilt to one side after several years, farmers understood the former granaries' advantages. Massive walls granaries mostly maintain their stability without any deformation for even over a hundred years.

3.4 Han village: Zhongshan

3.4.1 Village, dwellings and granaries

Zhongshan village, a mid-scale Han village with a population of 1,700 people, is located in the hilly areas of Mid-Fujian. In the past, the village was a stop of an ancient trade route passing through Fujian, thus also acting as a small regional market centre. Consequently, most of the local farmer families do not only work as farmers but also engaged in forestry, handicraft, and business (Fig. 3.22).

Fig 3.22 The satellite map of Chang Lingmao village, Sanming, Fujian.

Unlike Changlinmao, Zhongshan village was built on a plain area next to the river Xiyuanxi. The village layout was designed in a grid-like manner. The dwellings of the village were arranged along the main streets of the village, attached to each other. In order to prevent the spread of fire, high brick walls were built as divisions between neighbouring dwellings.

In Zhongshan village, the characteristic type of the local dwellings is a courtyard house consisting of a series of one-storey buildings. A typical courtyard house usually includes 2–3 courtyards, surrounded with buildings. Aside from these courtyards, some dwellings also have additional forecourts in front of the main entrances. Generally, forecourts, as well as fronted inner courtyards, are applied for drying rice during the harvest time (Fig. 3.23). These drying spaces are used in turns by all families living in the dwellings.

In such a densely populated settlement, there is no more enough land for building independent granaries outside dwellings. For this reason, farmer families generally store their grain in large grain cabinets inside their dwellings. Similar to Changlingmao, a dwelling of Zhongshan is usually shared by two or more families. Each family owns its private grain cabinet located in different corners of the house.

Fig 3.23 A forecourt for drying rice in a typical local dwelling.

The grain cabinets are mostly located in passageways in the courtyard house. Some of them are located in open verandas facing the inner courtyards. Some are located in the indoor corridors leading to kitchens. These various locations are more or less determined by two factors: access convenience and security needs of the grain storage. Both are essential for a granary.

Since brick walls, as well as wattle and daub walls, have been widely applied in local dwellings for many years, fire risk is no more a basic determinative consideration for the grain cabinets' location in a local dwelling. Nevertheless, local farmers are still inclined to put their grain cabinets in a place off the kitchen. In cases in which the grain cabinet has to be located next to the kitchen, as in the study case for this chapter, the owner would erect an additional wattle and daub wall as a fireproof screen in order to separate the kitchen and the grain cabinet.

3.4.2 Granary and its construction

Generally speaking, the local grain cabinets are mostly built with an unusual granary building technique. This technique has already been recorded in *Nongshu* (Agriculture book, 农 书), an agricultural technology book published in Yuan dynasty (Fig. 3.24). There are two advantages of this grain cabinet suggested in this ancient book: (1) it could be easily moved, and (2) it could be enlarged in a simple way.

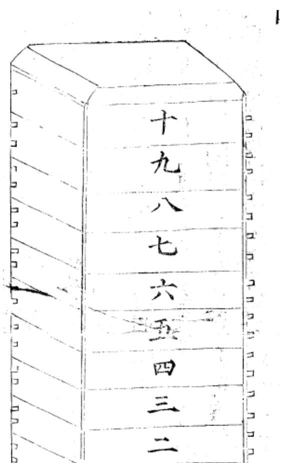


Fig 3.24 *Guigui* recorded in *Nongshu.*

The study case of this section belongs to a local family living in an ancient courtyard house. The grain cabinet, built in the 19^{th} century, with a storage volume of 2,000 kg, is located in a dark corridor leading to the kitchen in the house. The rectangular ground plan measures 2.1 meters by and 1.5 meters. All three walls surrounding the cabinet are built with wattle and daub (Fig. 3.25; 3.26).

Similar to the granaries of Chang Lingmao, there are two layers of protective covers existing in the front door of the grain cabinet: the swinging door and the inner movable wall. Furthermore, the grain cabinet was designed to open not only via the front door: The ceiling planks could be removed, allowing farmers to pour rice into the cabinet from the top. This opening option was used when the height of the rice stored within exceeded the height of the front door. Thus, this design allowed owners to store more grain. This structural versatility allowed an adaptation to the changing volume of the stored rice for daily consumption within one year.

The grain cabinet is comprised of several parts: a main massive wall structure, ceiling, floor, and door. The whole grain cabinet is supported by low stone bases (Fig. 3.27). Thus the floor of the cabinet can be lifted 20 cm off the ground. This lifting allows

Fig 3.25 The selected grain cabinet in Zhongshan, Sanming, Fujian.

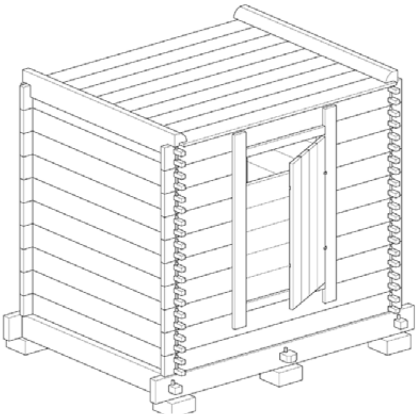


Fig 3.26 The 3D-model of the selected grain cabinet.

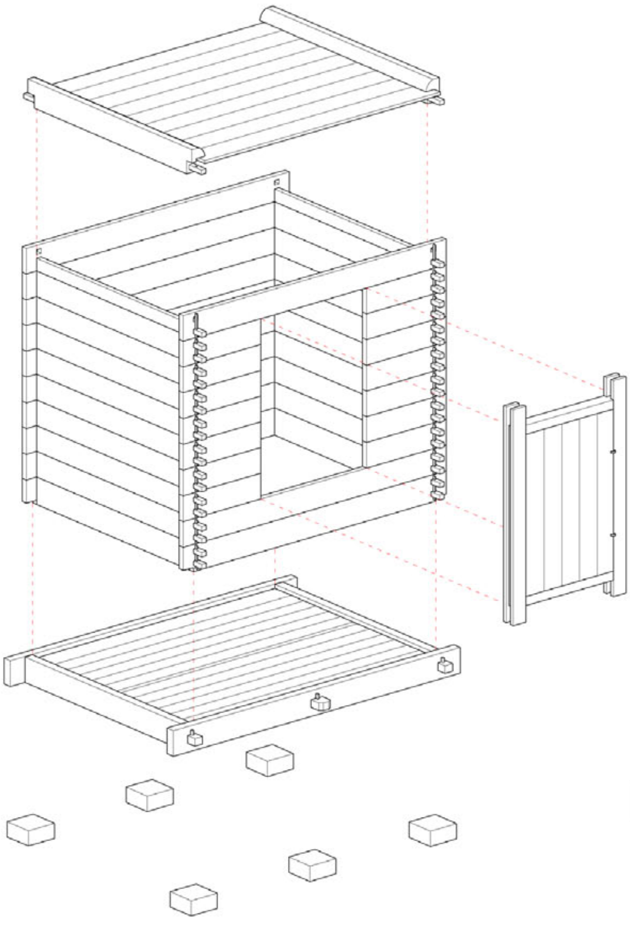


Fig 3.27 The grain cabinet is comprised of several parts: a main massive wall structure, ceiling, floor, and door.

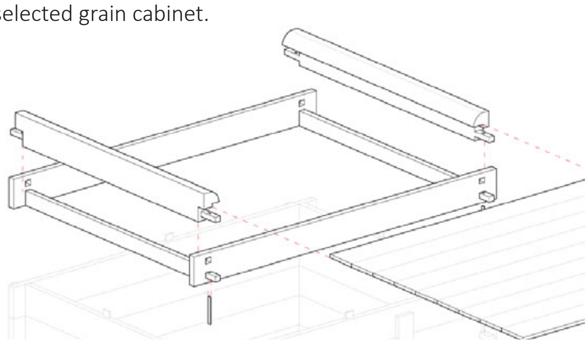


Fig 3.30 The construction detail of the ceiling of the grain cabinet.

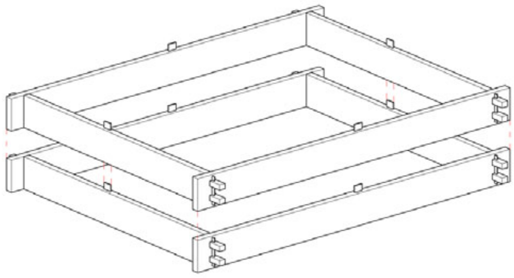


Fig 3.29 Bamboo dowels inserted between framed units.

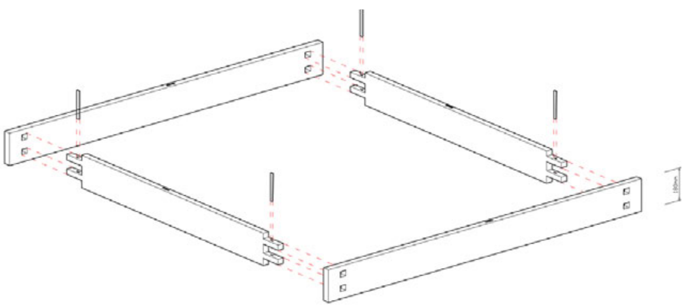


Fig 3.28 The construction detail of the framed unit.

necessary ventilation beneath the stored rice.

3.4.2.1 Wall structure

The main body of the grain cabinet is an unusual type of massive wall structure. This massive wall structure is assembled by several layers of wooden framed units all of the same shape and same height. Each frame unit is assembled by four pieces of wooden planks with an even height of 15 cm. To make rigid connections of the frames, each end of the transverse planks is shaped into double tenons, then keyed with the longitudinal planks by vertical wedges. The double tenons here are applied to strengthen the entire frame. Compared to the granary of Changlingmao, such keyed double tenon joints are stronger than the dovetail joints in resisting thrust from inside the granary (Fig. 3.28).

However strong these frames are joined, though, putting them simply above each other still leaves the construction dangerously weak. Carpenters thus installed rectangular thin dowels in between the frames to prevent any movement off the intended position. These dowels are situated centrally at all four sides of the frames (Fig. 3.29).

3.4.2.2 Ceiling and floor

The wooden planks of the ceiling are held by two transverse beams

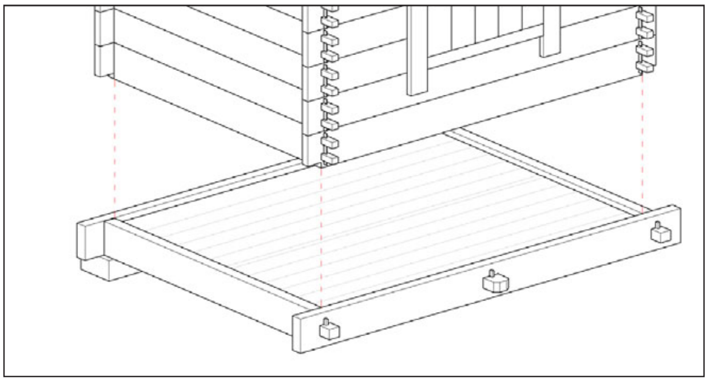


Fig 3.31 The construction detail of the base of the wall structure.

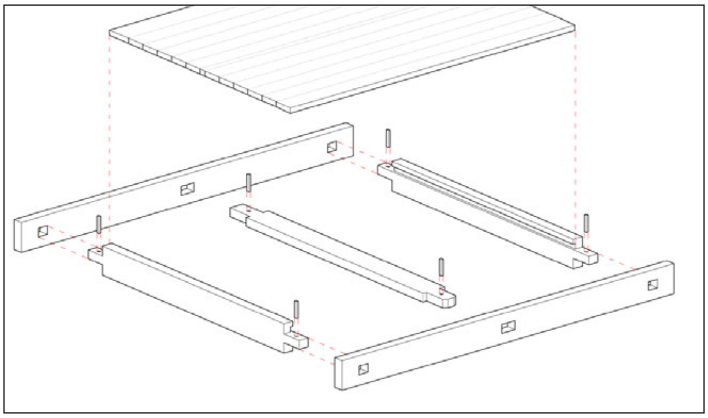


Fig 3.32 The construction detail of the lowest frame.

fixed to the lower frame. The carpenters' forward planning created grooves in the two transverse beams. Whenever necessary, it would be easy to remove ceiling planks in order to pour harvest from the top into the granary (Fig. 3.30). The two topmost transverse beams are joined with the lower structure again via tenon joints and hold the ceiling planks by the grooves at their lower inner sides. The transverse beams were shaped into rather complex forms in order to fulfil several different tasks: structural and functional.

The whole massive wall structure rests in a wooden frame box, which acts as the base of the grain cabinet. The form of the base is similar to the upper frame unit, but the ground plan of the former is slightly bigger. In the base, there is a floor surface installed in the plane 5 cm beneath the upper surface of the frame. The effect of this structural measure is to encase the base of the lowest wall frame (Fig. 3.31). The lowest frame carrying the floorboards overlaps the outer edges of the lowest wall frame in a position high enough to ensure that cereals cannot get lost through any possible gap between floors and walls.

Aside from the two transverse planks contributing the frame box, the floor of the cabinet is also supported by an auxiliary beam held in the centre of the longitudinal frame beams. This auxiliary beam is connected to the main frame with keyed tenon joints (Fig. 3.32).

3.4.2.3 Door

As in the granary of Changlingmao, the door frame is also fixed into the massive wall structure by its fork ends, but in a simpler way.

3.4.2.4 Summary

Due to their massive wall structures, grain cabinets relying on a double tenon construction method are characterized by the same advantage as other granaries with massive wall structures: strong and sealed. Compared to dovetail joints, the strength of the double tenon joints is even better. Additionally, the dimension of wall planks applied in the construction with double tenon joints can be thinner than the former one. Thus, by applying this construction method, farmers could save material.

We need to emphasize an important advantage of this type of grain cabinet. It allows owners to adjust the storage capacity simply without rebuilding the whole box or adding another one. Generally, the harvest of the farmers' fields slightly differs from one year to another for various reasons. In many other areas, such as Dong villages or Yao villages, carpenters built granaries significantly bigger than was required of an average harvest. Habitually, they felt responsible to provide storage space that could ensure sufficient capacity even in the case of an extraordinary large harvest. Some carpenters thought the other way around, however, providing a small cabinet with a storage capacity meeting the general output. Only if necessary did they offer a solution to extend the storage capacity. The main intention behind this design should be to save the limited indoor space. These granaries are mostly found in Han villages, where people prefer to put their granaries inside their houses.

However, the grain cabinet with double tenon construction also has its limitations. Firstly, using walls relying on many protruding tenons increases the area of exposed end grain. Exposed to outside weather conditions, such kind of grain cabinets cannot stay long. As a result, grain cabinets with such unusual construction have to be located in places under roofs. Additionally, the frame units forming the wall are only connected to each other with wooden dowels. These granaries' safety is limited, as anyone could easily open the cabinet without a key by lifting the upper frame units. Generally, it is difficult to ensure the security of such a grain cabinet when it is standing outside. Therefore farmers generally located these special grain cabinets in more or less hidden indoor places, such as dark corridors in the rear side of the house. In some cases, the farmers put a grain cabinet on the veranda facing to the open courtyard, and they would take some additional measures to hide the cabinets. A common option was to build a wall between the grain cabinet and the courtyard, in order to prevent outsiders from realizing the grain cabinet immediately when they enter the house.

3.4.3 Variants

The grain cabinet with double tenon construction might have been widely spread in the Han villages for hundreds of years, as it had already been recorded in Yuan dynasty. However, in non-Han areas, there can be found an example with a structure similar to this special type of Han grain cabinets. The Yi grain cabinet[9] is located in the main hall of an ancient Yi dwelling in South Sichuan Province (Fig3.33; 3.34). The grain cabinet is larger than the normal grain cabinets of Han villages. The structure of the grain cabinet consists of two parts: the inner box and the external frames, which is similar to the granary structure considered in Changlingmao. However, the corner joints of the inner box are double tenon joints, similar to the grain cabinets of Zhongshan. Different to the double tenon structure, the extended tenons are not keyed by small separate wedges but by the vertical pillars of the external frames. Carpenters cut out mortises along the vertical pillars, in order to house the extended tenons of the inner box in order to further fasten and fix

9. The primary measurements of the grain cabinet were drawn by Zhao Yun, the photos were taken by Liu Yan.

Fig 3.33 An ancient grain cabinet in Sigan Pu village, Meigu, Liangshan, Sichuan. (source: Liu Yan

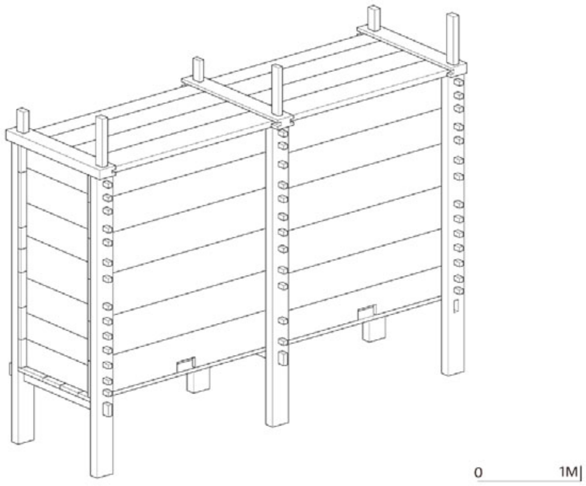


Fig 3.34 The 3D-model of the grain cabinet of Yi people.

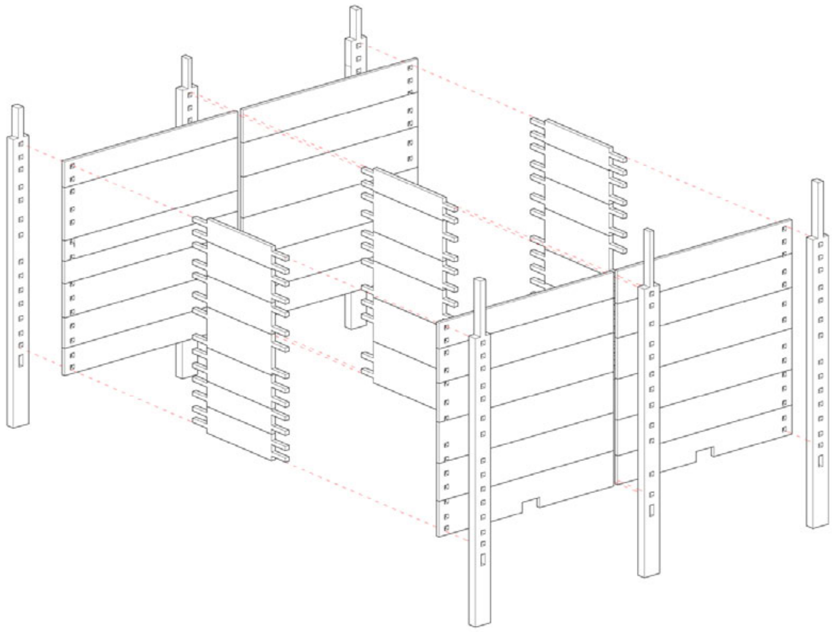


Fig 3.35 The construction detail of the grain cabinet.

the entire structure (Fig3.35).

As mentioned before, a major problem of grain cabinets with double tenon construction is that they could be opened easily by lifting frame units. In this Yi grain cabinet, Yi carpenters[10] solve this problem by applying wedges to key the external frames and the inner box together. However, the building method of the Yi grain cabinet again meets its limitation. Firstly, the carpenter had to cut mortises on pillars being next of the external frames in an irregular way according to the tenon arrangement in the inner box. This work should be done in a fairly precise way, requiring skilful carpenters. Secondly, the height of the horizontal planks would reduce more than the vertical members during the shrinkage progress, due to the different shrinkage rates along with the cross and longitude direction in timber. As the horizontal planks were tightly fixed to the vertical member, the shrinkage process would create gaps in the walls. In order to prevent these gaps, it is supposed that the timbers

10. It cannot be stated definitely whether the work was executed by Yi carpenters or enslaved Han carpenters.

selected for the grain cabinet would be totally dried before starting the building process. The processing of this special Yi grain cabinet is a difficult and specialized work that could be done only by skilful and experienced carpenters.

As such, this kind of structure way is found in Yi area rarely, due to the harsh requirements of its construction. We have reason to believe that the main intention for a carpenter to create such a construction was the owner's wish to demonstrate his power and status, as the only example showing such a structure was found in a local noble's dwelling.

3.5 Han village: Louxia village

3.5.1 Village, dwellings,and granaries

Louxia, a large village with a population of 2,300, is located in a hilly area along the coast. Based on certain statistics, the per capita arable land of Louxia is less than the average level of the province, which is around 0.51 *Mu* per person (溪柄镇人民政府, 2014). Due to shortage of the arable land, the local farmer families mostly work not only on rice cultivation but also on tea cultivation and forestry. As the village is located close to several important ports, in the past many male laborers went abroad to find jobs[11]. Thus, the remaining female family members had to carry out both the agricultural work and the household duties.

Similar to the other surrounding Han villages, Louxia village is located on the slow slope at the foot of the mountain. The dwellings are built up very densely in the village to save arable land and to reduce labour invested in the site grading (Fig. 3.36; 3.37). Narrow lanes and high rammed-earth out walls are applied between the dwellings, in order to prevent the spread of fire.

11. After 1950, the local tradition of males to look for jobs aboard came to an end. The reason is that the new policy of strictly controlling the border.

Fig.3.36 Louxia village, Fu' an, Fujian.

Fig.3.37 The satellite map of Louxia village, Fu' an, Fujian.


Fig.3.36


Fig.3.37

Fig 3.38 A traditional dwelling of Louxia.

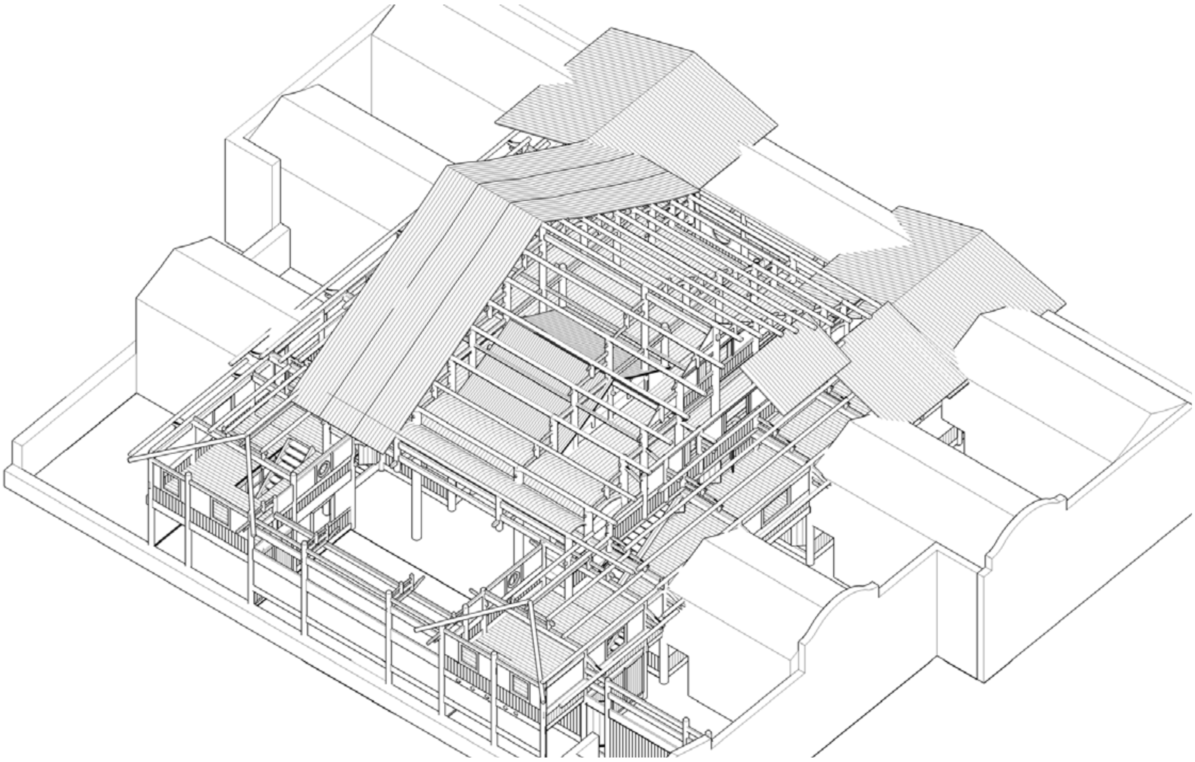


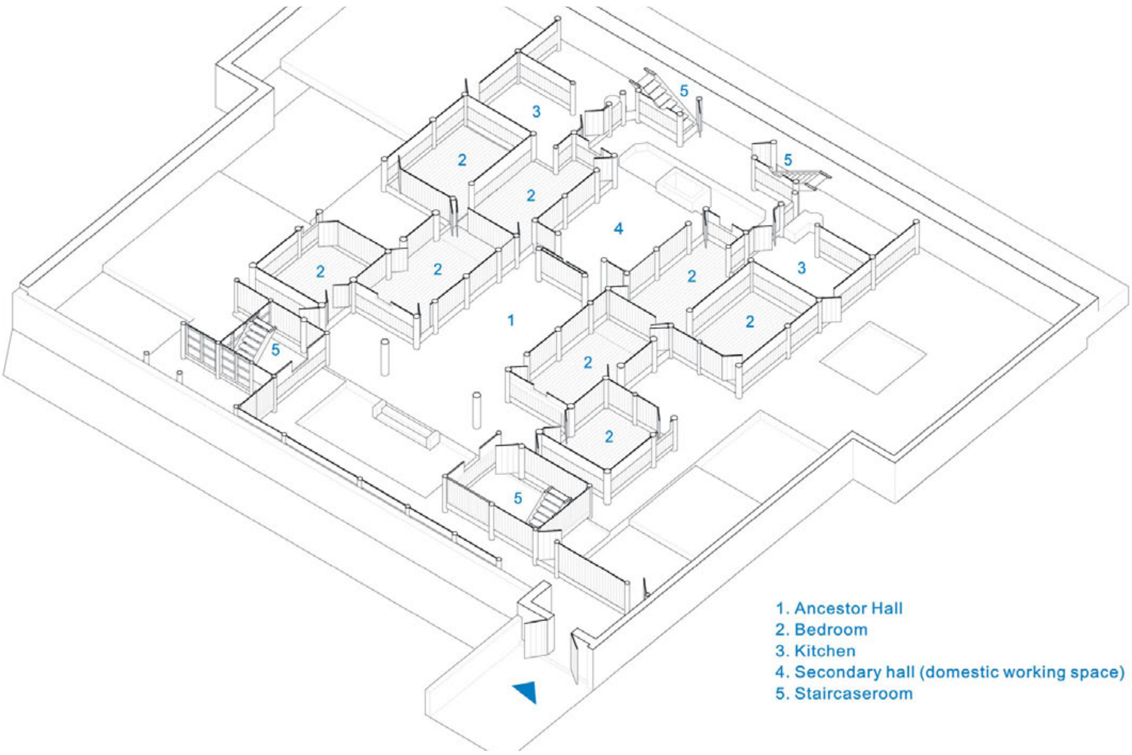
Fig 3.39 The 3D-model of the selected dwelling.

Affected by monsoon and typhoon, the annual rainfall of Louxia village located on the coast is greater than that of inland mountainous villages. Furthermore, typhoon season usually brings constant and heavy rains during from July through September（福建省福安市地方志编纂委员会, 1999), which used to be the period for rice harvests in this region. As the open-air rice-drying process could not be carried out successfully in the village due to the frequent rain during this period, local farmers needed to find a solution to protect their precious harvest.

Their unique form of the local dwellings could be interpreted as the answer to the rice-drying problem: A typical local dwelling is a large building integrating the living space, drying place and granary beneath one roof. The invention of this type of large buildings could also solve the general problem of shortage of drying places in the densely packed villages such as Louxia. In addition, since women had to carry out all household works and agricultural works themselves, a house that integrated the living space and the working space would be fairly helpful for them. Working in their own house allowed them to keep their eyes on their kids. In one Tibetan area of the Sha'er of Sichuan Province, women were also the asked to carry out all household works and most of the agricultural work alone. The local tower dwellings were also buildings that combined drying, storage, and residential functions (for further, see Chapter 6).

3.5.2 Dwelling and harvest process

Fig 3.40 The ground floor of the traditional dwelling.



The study case for this section is a typical local dwelling dated from the 19th century. It is comprised of a large core building and several wings, enclosed by high rammed-earth walls (Fig. 3.38; 3.39). Like most of dwellings in Han villages, the building is also a kind of multi-family house. Showing a symmetrical plan, the building was originally designed for two brothers' families. Each family would occupy half of the house. The central-bay space and the whole second floor could be shared by the two families, while the other parts were strictly separated. However, due to the shortage of building site in the village, the whole house is now shared by more than four blood-related families.

3.5.2.1 Ground floor: living area

The ground floor of the house is the living space for these families (Fig. 3.40). The main entrance of the dwelling is situated at the northeast corner of the whole building. At the entrance to the building is a veranda leading to the forecourt of the core building. There is one important ritual functional space on this floor: the ancestor hall. In local tradition, the ancestor hall also acts as the main living room of the whole house. It should be the most representative room showing the owner's wealth and social class. This space is covered by an interior roof（重栋）, acting as a canopy, in order to demonstrate the importance of this space. The central-bay is divided by a screen wall（太 师 壁）into two spaces: the front ancestor hall and the rear domestic working space. The rear court and the surrounding wings are service spaces, including two groups of kitchens and dining rooms . Rooms covered with wooden floors are all bedrooms, as shown in the Fig. 3.40.

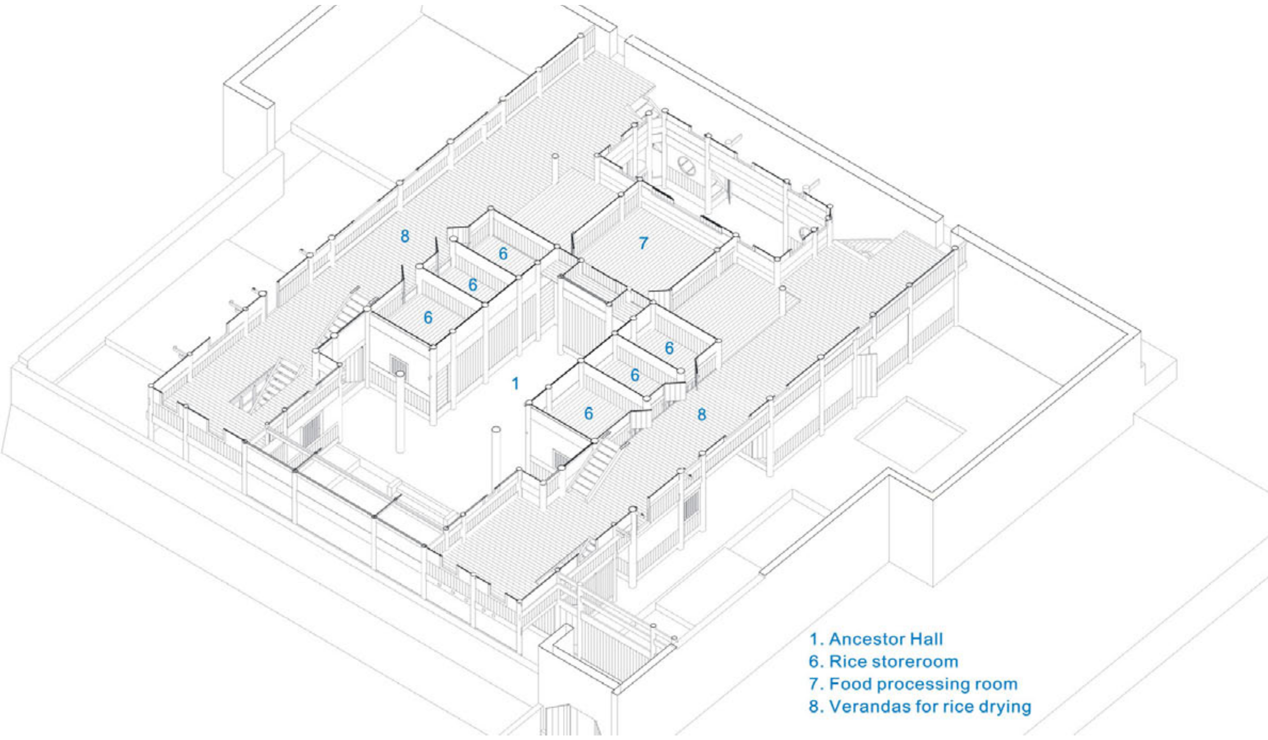
A type of important functional spaces were in place on the ground floor. We call them "staircase rooms," as each of them encases

Fig 3.41 The backside of ' harvest' doors in the dwelling.

a wooden staircase connecting the ground floor and the first floor. These rooms aim to solve the rice transportation problems inside the house. All the storage and drying places are located on the upper floor. In this house, there are four staircase rooms on the ground floor, separately belonging to the two families in this house. The two staircase rooms in the front courtyard are both for carrying rice to the upstairs drying places. The other two, in the back courtyard, are for carrying the rice downstairs to kitchens. Generally, one anterior staircase room, one posterior staircase room, and a corridor in between form one rice transportation route. The number of such routes in a house is usually the same as the originally planned number of families living in the house. The storage rooms are recognized as one of the most private spaces. Thus, each family would like to have their own separate route for transportation. When the number of families living in the house increases over time, farmers re-divide the space by adding partition walls and redistribute the stairs. Then the two staircases of one rice transportation route related to one family might reduce to only one.

In this house, the two rooms next to the forecourt are the anterior staircase rooms, as they are closer to the main entrance. Those two rooms are usually utilized for storing agriculture tools in the daily period. The narrow doors of the two rooms are all set in hidden places, where an occasional visitor would hardly notice them. It could be seen as a security method for the upstairs storerooms. However, during the harvest period, the narrow doors into the staircase rooms would be a hindrance for transporting rice. Local people usually carry grain with shoulder poles. This method of transportation requires a wide passage. Carpenters mounted a

Fig 3.42 The first floor of the traditional dwelling.



special type of doors for enclosing the staircase rooms to solve this problem. These “harvest” doors appear like wood walls erected as timber frame structure filled with vertical boards (Fig. 3.41). Closer inspection reveals that these planks are fixed to the door frames by wedges. During the harvest period, the owner can remove these doors by taking out the wedges and so opening wide passages for the rice transportation. In addition, the staircases were designed flatter and wider than ordinary staircases, in order to facilitate rice transportation.

3.5.2.2 The first floor: drying space and storerooms

The first floor is mainly designed for drying, storing, and processing food. We have enough reason to believe that elevating these functional spaces above the ground was partly based on the ventilation requirements, as necessary in the rice drying and storage process. Another consideration might be related to the lack of building land in the village. One researcher, Yang Zhiqiang, suggests that elevating storage rooms to the upper floor serves mainly to avoid storage rooms being damaged by flooding, a frequent occurrence in this region (杨世强, 2015, p. 118).

Due to the existence of the 7 meters high ancestor hall on the ground floor, the symmetrical plan of the first floor is mainly separated into two mirrors along the central axis spaces, which

Fig 3.43 Storerooms along a veranda.

could be utilized by two families, respectively (Fig. 3.42). Each part has its own staircases. In the back of the ancestor hall, there is a big room for food processing. This room is shared by two families, and each family has a door leading to this room. People are not allowed to pass this room from one door to the other, however. This kind of plan arrangement aims to ensure the privacy of the drying space and storerooms.

i.Drying place: Two long and wide verandas are attached to the core building. They are intended to serve as drying places during the harvest period. There are stairs located in the front ends and the rear ends of the verandas, respectively. Additionally, there are doors at the outer longitudinal sides of the verandas and in the back walls of the building which lead to the outside. These doors are prepared for outside temporary platforms. Some bamboo platforms are built attaching to the building, acting as a kind of alternative in the case there is not enough indoor drying space during the harvest time.

ii.Rice storeroom: In the back sides of both sidewalls of the central ancestor hall, there are six storerooms for storing rice. According to the initial design, each family would own three rice storerooms. Due to the generational increase of the families living in this house, some families have one storage room now, while others have two (Fig. 3.43). The average storing volume of one storage room is around 1,000 kg. Similar to other Han granaries, rice is stacked directly on the floors of these storerooms. The doors of the storage rooms are provided with high sills to prevent the rice from leaking out from the

Fig 3.44 The attic area of the dwelling.

room. The inner walls of the storage rooms are all coated with plaster, acting as fireproof coats, as well as a coat protecting the wood against rice's humidity and against worms in the rice. Additionally, the inner floors of the storage rooms are independently laid out, separated from the floors of the drying places. A similar separate-floor design can be found in granaries of Dong village Gaoding (for further, see Section 4.4).

iii.Food processing room: There is a connecting space between the two mirroring verandas which is included for food processing work, such as rice wine making and rice hulling. In some local dwellings, this space is an open space without a partition wall. It could be used as either a drying place or working space. In some dwellings such as the study case, there are two partition walls put in the central part to create an enclosed room. This working space was originally shared by two families.

3.5.2.3 The attic area: drying space

The attic area under the main roof is an open and high space, used in past as an additional rice-drying space during the harvest period. It was shared by all families living in this dwelling. The huge roof completely covers this space and the minor roofs of the ancestor hall and the front porch (Fig 3.44). Aside from sheltering more rice-drying space in the house, the huge roof also allows fresh air to blow unrestricted through the top of the house from one outside's gable windows to the other side. This measure provided a cooler and drier interior climate, good for drying and storing rice in the local humid and hot subtropical climate.

3.5.2.4 Remarks

When we try to analyse such a huge building, we cannot but judge it as a cheating. Houses always and everywhere were used as instruments of social status . Houses were used to demonstrate the owner's guest wealth and distinguished family background. Farmers did not want to be recognized as farmers. The first measure was to hide rooms and spaces giving evidence of their laborious everyday lives inside the house. This types of multi-functional dwelling appears to be an incarnation of these considerations. All working spaces are shut off from the observer's eyes. All functional spaces are kept invisible to unfamiliar guests. The carpenters were asked to create a stage, pretending an affluent lifestyle. They erected an ancestor's hall, appearing an impressive space with a height of 7 meters. They covered this space with a roof, in order to lead the visitor to confuse the real scale of the house, thus ignoring the huge hidden part behind the hall. From the outside, the main body of the dwelling is covered with a huge comprising roof, intentionally supporting the misunderstanding additionally.

3.5.3 Construction and details related to rice storerooms

In this section, I would like to focus on one problem: H**ow did carpenters integrate living space, drying platforms and granaries inside one building?** The analyses cover the following aspects: the main frame, windows and eaves, and walls.

3.5.3.1 Main frame

Due to its complex spatial arrangement, the timber construction of the dwelling is a fairly complex and huge wooden framework comprised of hundreds of structural elements (Fig 3.45). A detailed structural analyses shows that the main body of the huge timber construction is assembled by a three-bay core framework and two 10-bay wing structures attached to the core structure. The two wing structures, similar to the flying buttresses, support the core framework against side thrust, thus strengthen the whole structure to some extent.

The core framework is a *Chuandou* structure, mainly assembled by four large-scale *San* (Fig 3.46). Based on the requirement of building a 3-storied house, the height and the depth of these *Sans*（扇）are almost twice that of newly built dwellings in this region (Fig 3.47). In order to build such a high timber structure, carpenters applied the longest commercial fir timbers[12] for the central pillars in these *Sans*. In the transverse direction, carpenters added the amount of necessary pillars to increase the depth of the building as well.

12. *The timbers applied in the local dwellings are mostly commerce fir timbers, imported from the upsteam mountainous areas. According to the historical record, the length of longest commerce timbers is around 10-11 meters.*

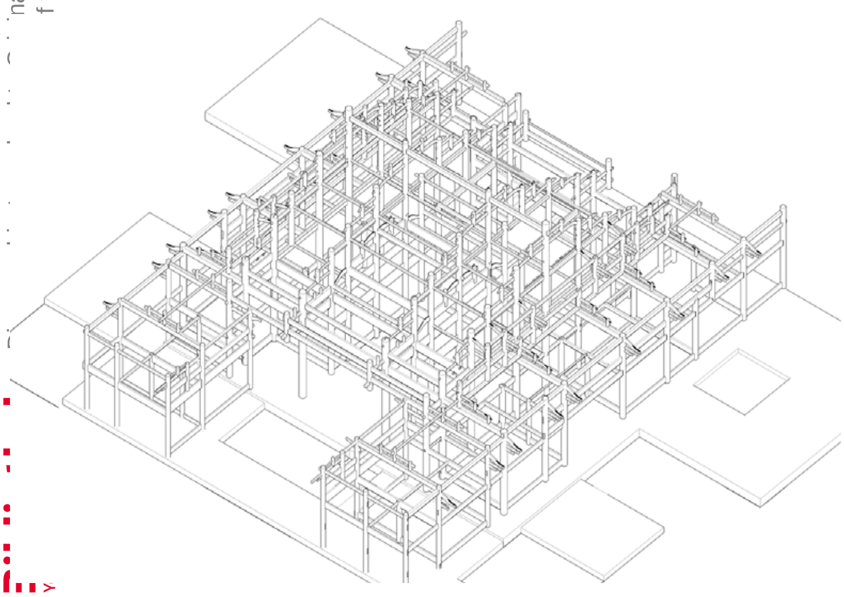


Fig 3.45 The main timber construction of the building.

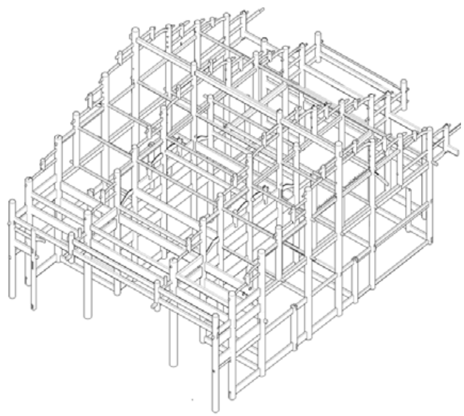


Fig 3.46 The core framework of the building.

The four large-scale Sans share the same outline but are built in two different patterns. The patterns of *Sans* usually follow demanded spatial function. The central two *Sans* are the same. They constitute the framework of the ancestor’s hall and the hidden working space in the rear side. Two other *Sans* are attached to them, forming the framework of storerooms, bedrooms, and working space. In general, the carpenters would intentionally enlarge the pillar spans of the food processing room and the drying space, in order to create an unrestricted working space without pillars (Fig 3.48; 3.49).

Setting storerooms above the bedroom causes a problem for the timber structure: the heavy load. Due to the controlled storage volume of storerooms, the height of the rice stack is usually so low that appears negligibly side thrust to the main framework. The main stress produced by the storage room on the timberwork is the load. Local carpenters realized this problem and tried to solve it in their way. According to the measurement, it can be seen that the joists supporting the floors of storerooms are much denser than those of the drying place.

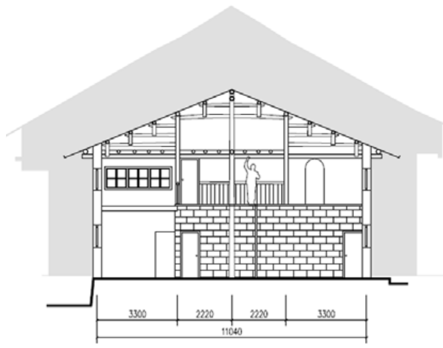


Fig 3.47 The section of a newly built dwelling. The gray area is the outline of a traditional dwelling built before the 1950s.

3.5.3.2 Windows and eaves

The local humid and hot climate requires promoted ventilation to dry rice inside a house. Carpenters opened a series of windows along the two verandas of the first floor and on the gable walls of the attic area, ensuring air ventilation convection above the interior

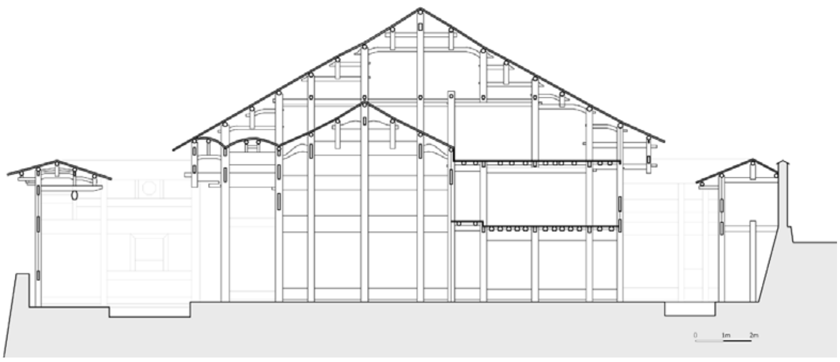


Fig 3.48 Section along the central axis of the dwelling.

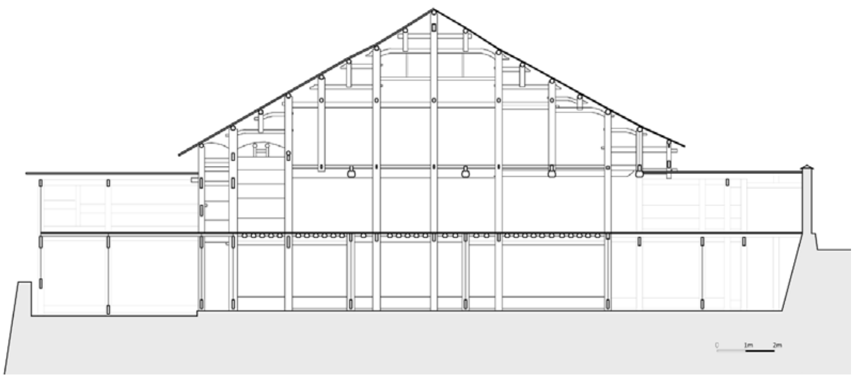


Fig 3.49 Section along a wing of the dwelling.

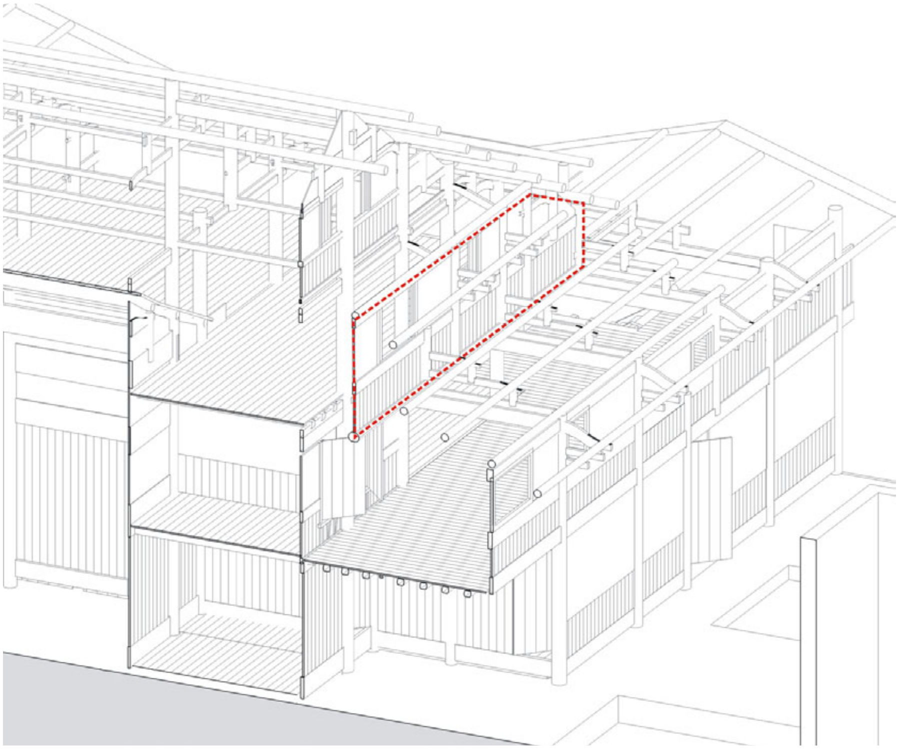


Fig. 3.50 A free-standing wall in front of the real gable wall.

rice-drying areas. Strong winds are characteristic of the coastal areas. Therefore, most of the windows are wooden sliding windows, which can better withstand strong winds. The people who lived in this dwelling faced another challenge: Rain is blown easily into the house if the wind is strong enough. Layers of Long cantilevered eaves were thus built above the windows, in order to fulfil two tasks. Firstly, they needed to protect the exterior wall, and secondly, they had to prevent rain from reaching drying spaces, as they might be blown through the window openings when the eaves are too short.

We need to mention a construction detail in the gable walls of the attic area. It can be interpreted as a sophisticated adaptation process developed over a long period of experience. The broad gable of the central part is two-stories high. Thus its wall's protection needs an additional pent roof. Due to the heavy rain, the pent roof had to protruded so far that its outer end needed additional supports. The carpenters created a win-win situation. They built an additional frame standing 1 m in front of the gable framework and made them into out walls. On the one hand, such outwalls can prevent rainwater from directly destroying the main structural pillars of the gable framework. On the other hand, this additional pillar row allowed an arrangement of pillar intervals independent of the main gable pillar arrangement. That means the size of window openings on these out walls could be chosen according to ventilation necessities (Fig. 3.50).

3.5.3.3 Walls

The study case consists of a huge wooden framework. As with all wood houses, fire is a risk for the families inhabiting in the house. Such houses multiplied the risk, as families stored all their staple food inside the home: rice provision for the whole year. The dwelling houses in Louxia are impressive examples of how kitchen and rice storing space could be integrated successfully in a house. This integration mostly relies on the application of fireproof building materials.

Fig 3.51 Plastered walls in a storeroom.

Closing a wall with wattle and daub is an ancient wall construction method based on a woven bamboo grid carrying an earth mixture that is finally plastered. It is light, simple, and fireproof. Wattle and daub walls are widely applied as interior walls in the local buildings. For the purpose of fire prevention, the areas surrounding the kitchen are mostly enclosed with wattle and daub walls. The walls of the storerooms are also wattle and daub, covered with heavy plaster (Fig. 3.51).

Rammed-earth walls and brick walls are used as out wall and enclosure walls of dwellings in Louxia. They are mostly taller than the inner attached roofs. This feature is seen as a way to stop fire from spreading along roofs.

3.5.4 Variants and changes

The local dwellings' integrating rice storage, drying place, and living space carried the following advantages:

i. They ensured that the long drying process of rice can be protected against weather influences such as typhoon.

ii. The integration of all those functional space in a three-storey building can save building land in such a densely populated village.

iii. Finally, the integration of all those functions provides enormous convenience for women who had to care for the household duties, as well as for agricultural tasks.

iv. As another advantage, we want to emphasize the enhanced security of a granary hidden inside a house.

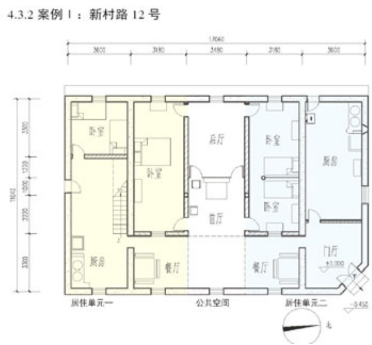


Fig 3.52 A plan of a newly built dwelling in a nearby village Liangchun (杨世强, 2015, p. 109).

Nevertheless, these types of multi-functional complex dwellings are vanishing. New dwellings built over the past 40 years differ significantly from the former dwellings. After the 1960s, accompanied by the promotion of the People's Commune, the forestry industry of Fujian suffered greatly and sharply declined (福建省地方志编纂委员会, 1993). This decline influenced Louxia's timber resources significantly. The available construction timbers in the following decades are were much shorter and of smaller diameters than before. It became impossible to build the same huge dwellings as before with such timber. As a result, dwellings built after the 1970s are mostly smaller and simpler than the former type (Fig. 3.47; 52).

The People's Commune activity also changed the local agriculture model. Before this policy was enacted , most rice fields were harvested in July and August, during the heaviest rainy period of the year. Yet, aiming at increasing the yield of the rice fields, farmers were asked to introduce rotational multiple cropping resulting in double rice harvests. Consequently, the local rice harvest period happened in June and October, thus avoiding the heaviest rainy period. This also had effects on the interior functional arrangement of the newly built dwellings. In a dwelling built in 1972, we could find that the interior drying place was already removed from the building, while the storage rooms were kept outside.

4. Wooden Granaries in South Guizhou and Its Boundary

4.1 Background

4.1.1 Environmental and social factors

This region is located in Southwest China, and at the edge of Yunnan-Guizhou Plateau. The majority of this region is mountainous area, which a number of valley regions. Compared to Southeast China, there is less plane area in the Southwest (Fig. 4.1).

Owing to its remote geographic location and poor natural resources, this area was at the edge of the governing network of the central government for quite a long time. Several different ethnic groups live here, including the Miao people, Dong people, Yao people, Bouyei people and so on. The Dong and the Miao account for the majority of the current population. This region had been independent of the Han regions for thousands of years. Headmen of local ethnic groups, mainly from the Miao and the Dong, ruled different areas of this region (赵晓梅, 2012, p. 56). In the Ming dynasty, accompanying the increasing population in South China, the central government wanted to seize further control over this region, aiming to secure more land resources. After a series of wars and political transactions, Han officials and the military gradually gained control over this area and ended its self-government (ibid.). In the same period, Han immigrants entered this region, competing with indigenous people for the limited land in the planes. This led to two results: the first was that many indigenous people had to move to some more remote mountainous areas. Some Yao and Miao villages immigrated into Yunnan. The second is that many Han immigrants chose to integrate into indigenous peoples' villages. This immigration happened most often in Dong villages (ibid.). We can imagine that these new immigrants brought their technology to these villages.

Due to the advantages of a large population and advanced agricultural techniques, Dong people occupied the majority of plains, valleys, and lower mountainous areas of this region. They knew how to build terraces and install irrigation systems, which allowed them to develop rice crops in mountainous areas. On the other hand, the Miao and the Yao, which were less developed, had

Fig.4.1 Location of Guizhou province and Guangxi province in China

to retreat to higher mountain areas, with fewer arable fields. The Yao people of the Yaoshan area, which is located in south Guizhou, still lived with shifting cultivation and were not sedentary until the 1950s (黔南布依族、苗族自治州史志编纂委员会编, 1993, p. 245).

The sizes of Dong villages are generally larger than those of other ethnic groups. An ordinary mid-size Dong village can house 157 families (around 655 people), such as Dengcen, while an ordinary Yao village usually consists of around 50 families. This can be attributed to the rice planting tradition of Dong people, which required collective cooperation.

However, arable land remains sparse in this region. Most indigenous people had to seek other measures to feed themselves. The Dong people traditionally engaged in forestry as well. The Yao in Yaoshan area (瑶 山) relied on anise planting and indigo planting for exchanging food (中国科学院民族研究所广西少数民族社会历史调查组, 1965, p. 32).

Belonging to the monsoon climate area, the local climate is quite humid. Local annual rainfall varies from place to place; in Sanjiang, it is around 1,439 ml, while in Libo, around 1,277 ml (《黎平县志》编纂委员会, 1989, p. 101; 荔波办公室, 1989, p. 42). The period of the rainy season varies in different locations. In southeast Guizhou, such as in the Liping area and the Sanjiang area, the rainy season lasts from mid-May to mid-September (《黎平县志》编纂委员会, 1989, p. 101). In Libo, the rainy season lasts from mid-April to mid-October (荔波办公室, 1989, p. 42).

This place is one of areas with the least annual sunshine in China, averaging less than 1,400 hours per year (刘明光, 1998, p. 45). Furthermore, the high altitude of mountainous areas makes them colder than the planes. It was thus difficult to plant normal rice here, very much in contrast to the sticky rice that would accept more difficult climatic conditions.

4.1.2 Staple cultivation and harvest

In valleys and lower mountainous areas of this region, sticky rice used to be widely planted. Sticky rice (*Oryza sativa var glutinosa*, 糯稻) is a special species of rice, more cold tolerant against the cold. Its yield is generally less than that of normal rice, however. The average yield of sticky rice in Liping area was 150–200 kg/Mu in the 1950s; this number has risen to 300–350 kg/Mu today, but it remains much less than hybrid rice yield (杨筑慧, 2014; 贵州省黎平县志编纂委员会, 1989). Based on the local special environmental conditions and the nature of sticky rice, the Dong developed a series of detailed and laborious cultivation technologies, aiming at maintaining their land fertility and ensuring good harvests. In many Dong villages of Guizhou, ducks and carps are intentionally raised together in rice paddy fields. This measure can help eliminate pests, add fertilizer to the soil, and provide meat for locals at the same time (石敏, 2016, p. 80).

Fig.4.2 Rice drying racks in a Miao village Basha, Guizhou

Sticky rice plays an important role in Dong's local lives and owns special cultural meaning. It is not only food, but also seed, gift, and divine offering (赵巧艳, 2015, p. 45). Some other ethnic groups living close to Dong villages, such as the Yao people, partly adopted by this idea as well. Thus, they all quite care about the harvest process and storage measures for sticky rice.

The harvest of sticky rice generally starts in October (杨筑慧, 2014, p. 370). Dong farmers usually use a special type of knife to reap sticky rice. These knives are called Hedao (禾刀). They believed this time-consuming harvesting method can reduce the loss of cereals during the harvesting process. Rice ears with straws then would be bound into bundles and carried to rice drying racks (Fig. 4.2). These rice drying racks are usually built along roads, streams, or steep slopes near villages. In some areas, such as Gaoding, farmers combined drying racks with granaries, providing more convenience. The drying process would last for around one month. Then farmers would store these dried sticky rice bundles into granaries. In some granaries, parts of rice bundles are hung in storerooms. Xinjing explains that this is a way that locals try to promote the air ventilation between these rice bundles, aiming to ensure the appearance and quality of the sticky rice, since it would be presented in some important ceremonies (辛静, 2014, p. 83).

Although sticky rice is cherished by the Dong and some other ethnic groups, the central government always saw its low yield as a significant disadvantage. Starting from the 1930s, normal rice was widely promoted in Guizhou province, as its yield was believed to be higher (杨筑慧, 2014, p. 58). In a statistics report concerning Liping area, the proportion of sticky rice planting had dropped to 30% in the late 1950s (《黎平县志》编纂委员会, 1989, p. 214). Normal rice still cannot adapt to the cold weather and lack of sunshine in some mountainous areas, though. The proportion of sticky rice planting area is still higher than that of normal rice in these places.

In some places of Guizhou, soil conditions are also unique. In Dongmeng and its surrounding areas, more than half of surface soils are lime soil, while arable soil suitable for rice planting is only 5.76% of the total land area, according to a statistics report in the late 1950s (荔波办公室, 1989, p. 17). The poor soil conditions forced local Yao people to live on slash and burn cultivation and to plant maize

(广西侗族自治区社会历史调查组, 1958, p. 68). Even so, products of their fields were usually not enough for the whole year's consumption for their families. Thus, they also relied on planting anise or indigo for to exchange for food. Only after the 1950s did the central government introduced irrigation technology and promote rice planting in this region. The Yao people then began started to settle down in certain places and to plant rice (中共大瑶山县委会, 1959, p. 1).

4.1.3 Forestry and Building technology

Several differences may be represented in forestry and building technology among different ethnic groups, especially between ethnic groups living in different environmental conditions. According to field investigations and interviews with local carpenters of different ethnic groups, this part provides information about the forestry and building technology of two different ethnic groups: the Dong people and the Yao people. The following parts would explain them separately.

4.1.3.1 Forestry and carpentry technology in Dong area

4.1.3.1.1 Forestry

Forestry used to be a pillar industry in Dong areas. Dong people had mastered afforestation technology since the 15th century (LUO, 2008, p. 100). The main tree species they planted was Chinese fir, mostly imported as building material to other provinces of South China.

However, the traditional fir forestry business was almost destroyed after the 1950s. The main reason is supposed to change in the land ownership relationship (LUO, 2008, p. 101). During the radical political movement of the People's Commune from the late 1950s through the 1970s, the private ownership relationships of the land were destroyed. The major part of the woodland was controlled by the government, while the rest woodland became the property of the so-called People's Communes, which were actually former villages. The abolishment of the private ownership drove locals to rush to cut out all the trees on the woodland of their people's commune, aiming to seize their own interests as much as possible (LUO, 2008, p. 102). In the following years, although local government tried to encourage local Dong people to recover their traditional afforestation industry, the uncertain land allocation system blocked locals from doing this, as before (LUO, 2008, p. 103). According to the literature and my investigation, the vanishing of the local traditional afforestation industry leads to logs' qualities significantly declining and their average sizes decreasing as well.

Fig.4.3 Carpentry tools of a Dong carpenter, Qingzai, Liping, Guizhou

Fig.4.4 A Dong carpenter worked with a ruler with a butterfly-shaped board in Dimen, Liping, Guizhou

4.1.3.1.2 Carpentry tools

Generally, the traditional carpentry tools of Dong carpenters are quite similar to Han carpenters. They use nearly all the same types of carpentry tools for cutting and shaping: axes, chisels, hammers, saws, and planes (Fig. 4.3). Experienced carpenters usually own several chisels with cutting edges of different widths. Most of them are specialized separately for preparing holes, preparing grooves, and shaping tenons and mortises. For cutting planks and beams from logs, carpenters used large frame saws and axes before the 1970s. It was heavy and labour-intensive work. According to locals' description, mechanical saws were introduced into villages in the 1970s, which then became widely used for cutting.

Field investigation reveals that there are many types of measurement tools used in the Dong's building constructions. A wooden ruler, square, and tape measure are widely used among Dong carpenters, similar to the Han. Master carpenters additionally used several special measure tools for measuring and marking wooden components in large scale building projects: long wooden sticks with marks, short wooden strips with marks, and a ruler with a butterfly shaped board at its end. Carpenters marked intended length of pillars and beams on long wooden sticks, and used them as rulers to measure and mark construction timbers (辛静, 2014, p. 34). Short wooden sticks were marked with dimensions of tenons and mortises. They were usually used with a ruler with a butterfly-shaped board. They can facilitate the production of wooden joints and ensure engineering accuracy (Fig. 4.4).

4.1.3.1.3 Building process[1]

Chinese fir is the main building material for the granaries of Dong people. Due to the local traditional forest industry, this building material was abundant in Dong villages in the past.

1.This part is mostly based on the interviews of two local Dong carpenters: Wu Longbi (吴龙义) and Zhang Yigao (张译高).

Trees can be felled twice a year: at *Qingming* (清 明 ,usually in April) and during a period after rice harvest (mid-September to October). The practice of felling trees in the spring is usually associated with the requirement for large pieces of barks, since fir barks were widely used as roofing material in the past. However, accompanying with the widespread introduction of clay roof tiles, fir barks are less demanded for roofing now. The majority of carpenters prefer logging in autumn. They believe that trees contain less sap in autumn and winter. Timbers felled in this period can be more solid and less susceptible to pests.

Before logging, the client and the master carpenter would firstly go to the client's own fir forest to select and mark qualified woods for pillars: in lower mountainous areas, fir trees older than 20 years are qualified to be used as building timbers, while in higher mountainous areas, only fir trees of over 30 years are qualified. The latter is thought to be the ideal material for granary construction. However, due to the decadence of the traditional fir tree forestry businesses in this region in recent decades, locals sometimes even need to import large timbers from other places for some special construction projects such as drum towers. The diameters of the timbers for building granaries also become smaller.

After logging, the barks of the fallen trees were immediately peeled off by axe. Branches could be left. Carpenters believed that preserving branches could speed up the drying process, facilitating water evaporation from the trunks. All trunks would then be left on the mountain for two months. During these two months, trunks would lose part of their water and some of their weight. This weight loss facilitated the transportation step. Branches were cut off before transportation.

Trunks were firstly carried to a conventional woodworking place in the village. In many villages, these woodworking places were next to rivers, sometimes also next to main roads. Carpenters would then deal with trunks for future beams and planks, cutting them into the desired shapes. These beams and planks would then be stored with logs for pillars together in the woodworking place or some other ventilated places for further drying. According to the logs' different future functions, carpenters usually set different drying durations for them. The ideal drying duration of wooden planks is around seven months, and the drying duration for the pillars can be as little as two months. This reveals that Dong carpenters noticed and cared about the influence of wooden members' shrinkage in building construction.

As soon as a master carpenter detected timbers that had been already dried to a certain degree, the process of making building components starts. A working group usually included a master carpenter and his apprentices. Sometimes local villagers with some carpentry knowledge joined the group. The master carpenter designed houses according to site conditions and client's requirements. For some large-scale buildings, he would draw plans and sections. When he has a general idea of the building, he then mark all needed data of the building's components and joints on wooden strips and draws ink marks on logs with help of these wooden strips. These marks instruct other workers to correctly shape the works. Generally, four men are needed to work for five days to complete the whole process of preparing the components for a small granary.

Belonging to the *Chuandou* system, the framework of a Dong granary is assembled by a series of parallel *San* (transverse frames) and longitudinal connecting beams. Carpenters complete the assembly of all transverse frameworks on the ground before the day the building is erected (hereafter abbreviated as construction day). This step can save the investment of time and labour on the construction day.

A lucky day should be selected in advance to erect the granary. According to the Dong people's tradition, *Biri* (闭日)[2] is the best day for granary construction, as people believe that the granary built on that day could be better sealed. The main framework of the granary and the roof should be completed on this day, while the rest can be finished the following days.

On this selected day, 20–30 relatives[3] of the client's family come to help. The required number of participants depends on the scale of the granary. During the erection, two parallel *San* are firstly erected by aid of bamboo sticks and ropes. Then a group of longitudinal tie-beams is installed tenoned into pillars of the two *Sans*. The built preliminary framework can then stand freely. Depending on the scale of the granary, the next erected *Sans* is attached to the former framework by another set of longitudinal tie-beams defining the distance of two *Sans*. This process is repeated sequentially until all *Sans* are tied by longitudinal tie-beams (Fig. 4.5).

2.*Biri* (闭 日) : literally means closed day. According to the traditional East Asian calendars, every twelve days there would be one closed day.

3.The majority of Dong villages are clan villages. It can include one clan or several clans. Families of one clan generally have far or close relationship to each other.

Fig.4.5 Carpenters tied the longitudinal beams with two san in the construction day of a dwelling. (source: 尹忠)

Fig.4.6 Adjustment work after the erection of the main framework.


Fig.4.5


Fig.4.6

After the erection of the granary's framework, some adjustment works are carried out in the second day (Fig 4.6). The further construction tasks, such as installing purlins and covering tiles can be executed in the following weeks. Walls, ceilings, and floors made from wooden planks can be finished at a later time, depending primarily on the economic condition of the owner. Before a new granary is suitable for use in storing grain, quite a long time must pass after construction day .

Throughout the whole construction process, the major part of construction work, including the processing and assembling work, can be carried out by just a small group of workers. These works can be done in a convenient place on an even surface, as building sites in Dong villages are usually too narrow for woodworking. However, there is one building procedure that usually requires a great number of people: erecting the main framework. The Chuandou structural system allows carpenters to assemble transverse frameworks before construction day . Thus the whole erection process can be finished in one day. The process of erecting a building is strongly influenced by demanding conditions in the mountainous areas. The construction site is narrow and usually on a hill slope. Therefore, the Dong people developed a building process facilitating the given challenges.

4. This part is mainly based on the interview of local Yao carpenters.

4.1.3.2 Forestry and carpentry technology in Yao area (Libo region)[4]

4.1.3.2.1 Forestry

Due to the traditional migrating living mode, most Yao villagers in Libo area are accustomed to obtaining their building materials from the surrounding natural forests. This habit had a certain influence on their preference for tree species for construction timber. Yao carpenters generally believed that Masson's pine was best suited for building granaries. Maple is also considered to be a good timber for building, but they thought that maple planks would tend to warp. Warped boards are unfavourable to ensure dense walls and an even plane in granaries.

4.1.3.2.2 Carpentry tools

The introduction of mechanical saws in the 1960s–1970s brought substantial change to local building technology. Mechanical saws make it easier to obtain timber and facilitate the tree-conversion process. According to locals, more and more wooden granaries with rectangular plans were built after the 1970s. This increased construction was likely related to the application of mechanical saws.

Very few little is available about the Yao's traditional carpentry tools before the 1970s. Some literature has indicated that they owned quite few iron tools, including simple axes, chisels, planes, and small saws in the 1960s (中国科学院民族研究所广西少数民族社会历史调查组, 1965, p. 34). Local carpenters explained that their ancient bamboo cylindrical granaries could be built by axes and chisels in a simple manner.

Today, the main types of carpentry tools of the Yao are quite similar to those of the Dong and the Han. However, numbers of subtypes of carpentry tools of Yao people are still far fewer than those of the Dong and the Han.

4.1.3.2.3 Building process

The preparation process of the building material usually starts in August. According to local tradition, wood logging can only start after *Liqiu* (立秋)[5], which is normally in the middle of August. Locals believe that timbers felled in this period are more solid and resistant to termites.

The timber drying duration in this area is much shorter than that of other places. It usually lasts only 10 to 15 days. As soon as logs are felled, all bark and branches are cut from the trunks. Additionally, rough mortise holes would be dug out on the logs at the same time by carpenters. This these holes can be seen as a simple measure facilitating water evaporation from the trunks. These rough wooden members are left on the mountain for two days before erection day.

Then logs need to be carried to the construction site. Carpenters do further processing work to prepare the granaries' components for assemblage. For a cylindrical granary, bamboo walls are prepared during these two days. On the selected construction date, usually a so-called lucky day in the Yao's traditional calendar, the owner's relatives and friends come to help. The main structure is erected in one day. Covering tiles and inserting planks can be left to be finished in the following days.

In the case of the cuboid granaries, the owner will leave the granary empty for 2–3 years after its completion. After this interruption, the carpenter removes the roof structure, seals the walls, ceiling, and floor, and finally fastens the topmost tie-beams[6] with a hammer. It can then be used for storage.

5 Liqiu(立 秋), the 13th solar term of traditional East Asian calendars.

6. Topmost tie beams of cuboid granaries are of special forms which allow their members movement. This would be explained in a llater section.

Fig.4.7

Fig.4.8

Fig.4.7 The Yao village:Dongmeng, Libo,Guizhou

Fig.4.8 A typical dwelling of Dongmeng in nowadays.

4.2 Yao village: Dongmeng

Dongmeng is a Yao village located in Libo area, southern Guizhou. The village hosts 57 families, most of them nuclear families. Generally speaking, an ordinary local family consists of three to five people.

Due to the poor local soil conditions, Yao peoples practiced slash-and-burn agriculture. Consequently, Yao villages frequently moved in this area. Maize was the main crop planted by local Yao farmers in that period. In the late 1950s, local governments tried to transform this "regressive" cultivation model by importing "advanced" cultivation knowledge into this region (中共大瑶山县委会, 1959, p. 7). The introduction of irrigation systems in this region promoted rice cultivation in its valley areas. As a result, both maize and rice became staple crops for local farmers. The change of agricultural methods largely promoted the change of the local ways of living over the 20th century . Most Yao villages of this region gradually became to permanent settlements in the 1950s; Dongmeng village is one of these (黔南布依族苗族自治州《概况》编写组, 2003, p. 245).

4.2.1 Village, dwelling ,and granary

The main part of the village is located on a slope of a mountain(fig 4.7). A central plaza acts as a public drying place in the root of the mountain. Many granaries are located on the topmost border of the village.

Twice the local dwelling form has experienced substantive changes during the last century. The first was likely to be related to the introduction of new wood building technology around 1960. The second was due to the introduction of clay tile production technology in the late 1970s. There is nearly nothing left of old Yao dwellings built before the 1960s, aside from some records. The local official documents depict old Yao dwellings as primitive thatched huts assembled from rough branches and trunks with barks. The structural elements are bound together (Weiyuanhui, 2003). These kinds of buildings were replaced by so-called *Ganlan* houses, which are wooden buildings with a raised floor and covered with a thatched roof. Since tile production technology was imported in the late 1970s, all thatched roofs of dwellings were then gradually changed into tile roofs. Now all current dwellings are wooden houses with a raised floor and covered with roof tiles (Fig 4.8).

Accompanying changes in building technology, the layout of the village has also gradually changed. When all Ganlan dwellings were covered with thatched roofs, the general distance between buildings was recommended to exceed 10 meters. Locals explained that size this was specified due to fire-prevention measures. After the introduction of clay roof tiles and their wide application in dwellings, people were convinced that fire risk for the village was reduced. Since the 1980s, new granaries were built closer to the dwellings.

The change of roof material effected locals' selection of construction site of a new granary as well. In Dongmeng, many granaries were located on the topmost end of the village, keeping a distance from the residential area. Meanwhile, some granaries were connected to dwellings (Fig 4.9). Setting granaries on the highest place of a village is a conventional practice among the Yao villages of Guizhou, as higher places can usually offer better ventilation, which is good for grain storage. Meanwhile keeping granaries far away from dwellings is an effective way to prevent destruction from fires. However, the disadvantage of this choice is also obvious. When a granary is too far away from its owner's kitchen, it causes inconveniences in daily life. Thus, some local people moved their granaries next to their dwellings, as soon as they had realized that the tiled roof could

Fig.4.9 A granary covered under the extened roof of the dwelling.

Fig.4.10 A cylindrical granary.

Fig.4.11 A cuboid granary.

effectively reduce the dwelling's vulnerability to fires. As a result, all granaries located next to the dwellings are covered with tile roofs, while granaries with thatched roofs were located far away from the dwellings.

4.2.2 Granary and its construction

In Dongmeng, each family has one granary. A granary is a sign of an independent family. When a young couple was married and split from their parents' families they needed to build their own granary as soon as possible. From another perspective, this custom also implies that the locals usually do not expect the service life of a granary to last over 100 years.

There are two major types of granaries in Dongmeng: **cylindrical granaries** with bamboo walls, and **cuboid granaries** with wooden walls (Fig 4.10, 11). Cylindrical granaries, are mostly built of bamboo and wood, with thatched roofs. Locals call this type of granary an "ancient granary", since they believe the building technology of this type of granary was passed down by their ancestors. On the other hand, cuboid granaries, most of which were said to be built from the 1970s to the 1990s, are wood structures with tile roofs. Locals explained that they learnt to build this type of granary from the Bouyei people[7] in the 1970s (童亚, 2014, p. 29). Cuboid granaries are now the majority in this village.

7. Bouyei People(布依族): an ethnic group living mostly in Guizhou Province, China.

Both types of granaries are equipped with raised floors. These floors are lifted around 2 meters off the ground. One consideration for such a design is ventilation, while another consideration is stopping animals and strangers from entering storerooms. To climb into the granary, one needs a ladder. It must be removable to prevent rats from entering the granary (Fig. 4.12).

There are two conditions of storing cereals in a granary: being stacked directly on the floor or being packed in plastic bags standing on the floors. Investigation reveals that both options can be applied at the same time in one store room. A key point is that maize and rice should be stored separately. When the granary has two rooms, one room should be used for maize and the other for rice. Bundles of sticky rice on their stalks would commonly be hanged on the inner wall of the granary. Locals explain these bundles are prepared as gifts for some occasional important ceremony (Fig. 4.13). Rice is stored in plastic bags and then put inside the granary. This method can prevent leak of cereals and can be seen as a simple way of deterring insects.

Fig.4. 12 People usually use a ladder to enter the granary.

Fig.4. 13 Bundles of sticky rice are hanged on the inner wall of the granary.

4.2.2.1 Cylindrical granary

A typical cylindrical granary of Dongmeng generally is covered with a thatched roof and enclosed by a woven bamboo wall. Similar characteristics can be found in many ancient cylindrical granary models of the period between the Zhou dynasty (1046 – 256 BC) to the Han dynasty (202 BC – 9 AD; 25 AD – 220 AD) (Fig. 2.27). Cylindrical granaries are called *"Qun"* (囷) in Chinese, as people want to distinguish them from cuboid granaries. Qun models are likely to be the earliest granary models found in Chinese history. This supposition is related to their simple construction. As shown in archaeological reports, cylindrical granaries also used to be widely used in North China during this period (for further, see Section 2.3.2) .

Another obvious characteristic of cylindrical granaries in Dongmeng is their raised wooden platform. The raised wooden floor can facilitate air ventilation beneath the stored grain, thus reducing the indoor humidity and high temperature. This feature can be seen to be developed under local warm and humid weather. A similar feature can also be found in many Qun models of the Han dynasty, which were all found in South China.

Cylindrical granaries offer certain clear advantages according to locals. Their construction could be completed quickly. Their simple building method allowed ordinary farmers to build their own granaries only with axe and chisel. These granaries also had disadvantages, however. Both thatched roofs and bamboo walls are easily destroyed in humid weather. Owners need to do restoration work regularly, which is quite time-consuming. Additionally, bamboo walls are less sealed and stable than are wooden walls. They are easily deformed only a short time after construction.

Although all cylindrical granaries present similar primitive appearances, my investigation indicates that there are two different subtypes of these granaries with different major frameworks (Fig. 4.14).

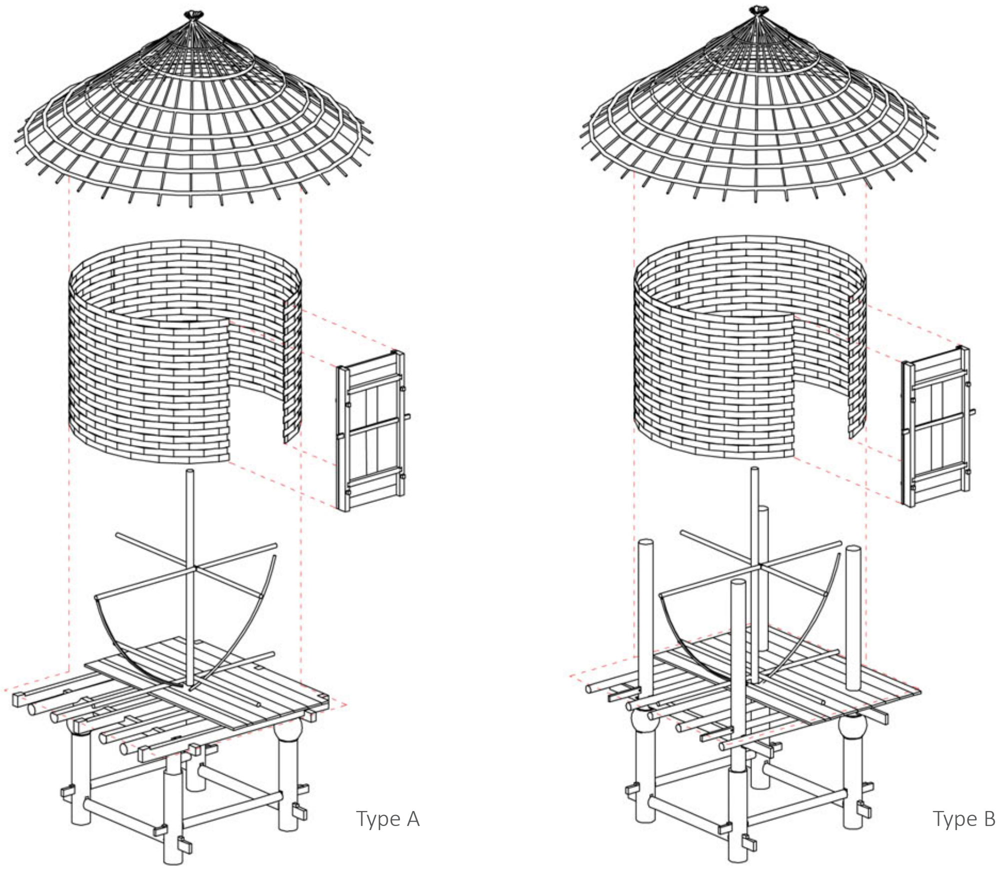


Fig.4. 14 Two types of cylindrical granaries: type A and type B.

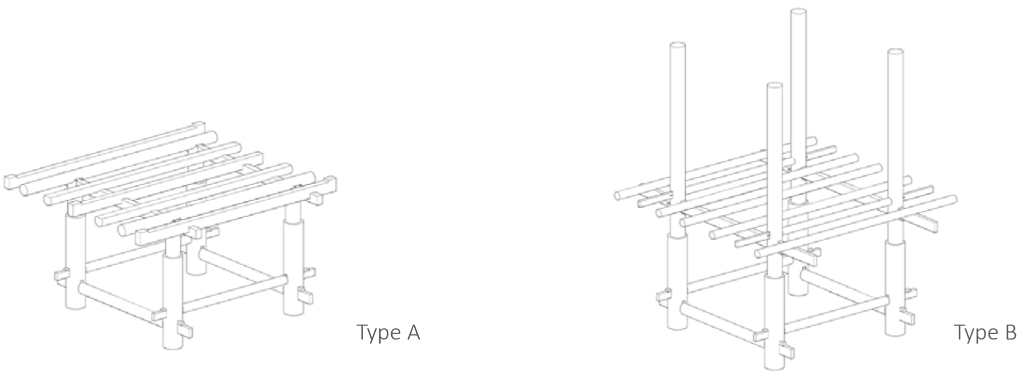


Fig.4. 15 Two types of main frameworks used in cylindrical granaries

4.2.2.1.1 Framework

In general, the supporting structure of a cylindrical granary is assembled by two separate parts: inner frame and major framework. As shown in Fig. 4.14, an inner frame consists of thin branches that are bound together and put on a raised floor. The main function of these inner frames is to support the upper roof and woven wall. It is done with tied joints in a rough way. The major framework, which is usually assembled by finer wooden members, carries all loads of stored grain and the upper structure, including inner frame, roof, and wall.

Detailed investigation shows two types of major frameworks used in Dongmeng (Fig. 4.15). I call them Type A and Type B in this part. Type A can be seen as a platform. Floor joists act as tie-beams in this structure. Notches have been cut in their underside. These notches allow these floor joists to fix perpendiculars two beams beneath, thus forming a stable plane frame. This frame is housed into four fork ends of lower pillars. Thus, the tops of these pillars are then fixed with the frame. Meanwhile, one layer of tie-beams exists in the lower part of the major frame, ensuring the stability of this major framework. Wooden wedges are used in mortises to strengthen their connections. Type B is characterized by longer pillars and two layers of tie-beams. Floor joists are the only loadbearing members in this structure. In the two layers of tie-beams, the lower layer of tie-beams uses wedges to fasten the structure, while the upper tie-beams apply keyed joints.

Generally, a keyed joint is harder to complete than a simple through-mortises joint, since the former one requires more labour and needs to be calculated precisely. Nevertheless, both are harder to make than are housing joints. Consequently, we can get an idea that the building process for Type A might be easier than that of Type B. This assumption is affirmed by local carpenters. They said that type A could be built in a short time just using axes and chisels. However, the disadvantage of the framework of Type A is also obvious: the separation of upper and lower supporting structures can easily result in structural deformation in a short time. I assume that during the introduction of technologies in the village in the 1960s, some local carpenters wanted to integrate new methods, such as the usage of keyed joints in their traditional granaries, aiming to enhance the stability of the whole structure. Thus, they elongated the pillars of a granary to resist the lateral thrust caused by stored grain and used stronger keyed joints to bind the structure. The result is Type B.

4.2.2.1.2 Roof

The cylindrical granary was generally covered by a thatched roof. Its outline should cover the whole square wooden floor. A typical roof structure of cylindrical granaries is a simple umbrella construction (Fig. 4.16), consisting of dozens of branches bound as rafters to the central pillar. It is propped by the central pillar and bamboo wall beneath. According to the interviews with locals, restoration works to the roofs should be undertaken every four or five years, such as adding new straw to ensure the rainproofing.

Fig.4.16

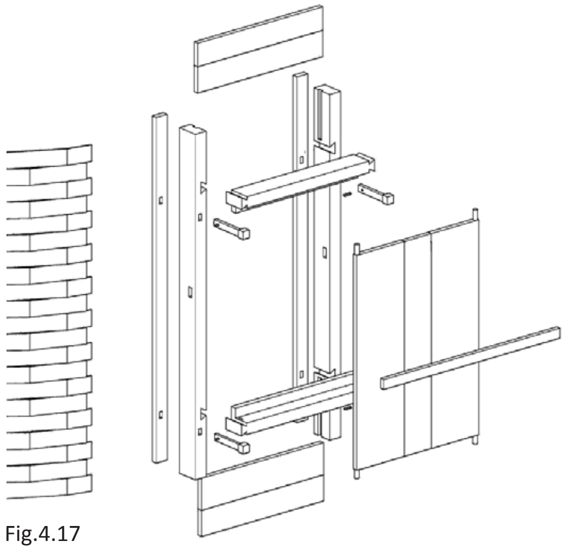


Fig.4.17

Fig.4. 16 A simple umbrella roof structure.

Fig.4. 17 Ends of the bamboo mat are fixed with wooden nails on the door frame.

4.2.2.1.3 Wall

The wall of a cylindrical granary is a piece of woven bamboo mat connected by a special wooden door frame. Both ends of the bamboo mat are fixed with wooden nails on the door frame (Fig. 4.17). The inner frame also contributes to support the woven bamboo mat. In the case of Type B, its wall is bound to four pillars.

Bamboo walls are easily damaged during humid weather. Thus regular restoration works or rebuilding work must be done every four to five years. In some cylindrical granaries, the owners plastered mud on bamboo walls as a measure to ensure the sealing of the wall. In order to prevent insects, the bamboo walls of granaries are to be smoked every year before storing the grains at harvest time.

4.2.2.1.4 Floor

Generally speaking, the raised floor of a cylindrical granary is composed of wooden boards.

The floor's sealing is an essential requirement for granaries, especially when storing cereals. It is a challenge to avoid gaps in the wooden floor that occur due to the process of wood shrinkage. All wooden planks were prepared when they were still unseasoned at this location. Locals found a way to respond to the shrinkage of these floor planks. Adding a long wedge should offer a chance to react the material shrinkage. They insert the narrow end of a long wedge between two central floorboards during the construction process. This action would fasten the whole floor at the beginning. However, due to the shrinkage process, the widths of each wooden floor plank is reduced in the following one or two years. Gaps thus

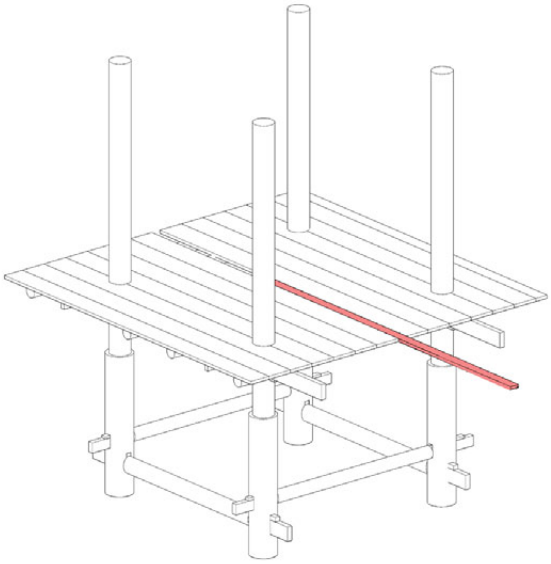


Fig.4. 18 The fastening method of the floor construction of granaries of Dongmeng

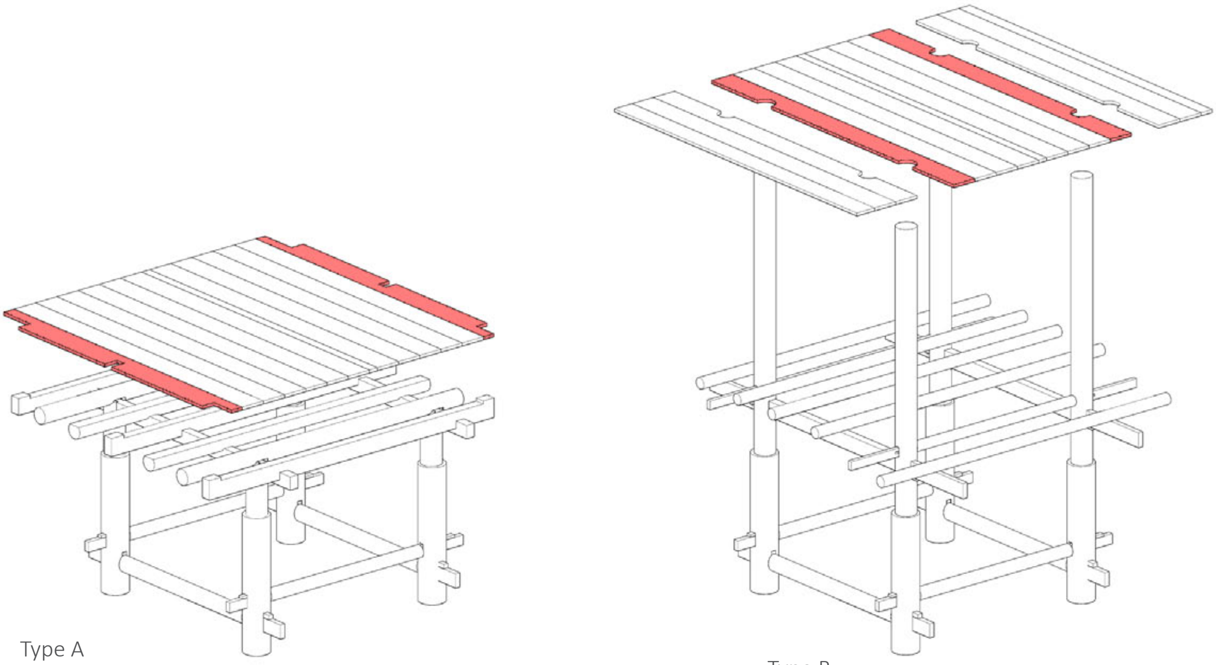


Fig.4. 19 Two types of floor constructions.

occurr in the floor. The carpenter came and kicked the protruding end of the long wedge into the floor. This practice eventually fastens the whole floor (Fig. 4.18).

However, the premise of such a fastening measure is that both ends of this floor must be fixed against giving way to the outside. This method can prevent the disintegration of the floor under the fastening process. In Type B, pillars help to fix the floor, while Type A, without pillars elongated above the floor, had a problem. The floor boards were not prevented from giving way, being pushed outside the building . Then local carpenters prepared to fix the outmost joist in order to fit the boards in the intended way. They reduced the upper part of these two joists' section by approximately 3 cm.

Only the end parts of the joists, about 8 cm, were left untreated. Sometimes, they worked a central joist in the same way as well (Fig 4.19).

4.2.2.1.5 Door

A door should be the most refined carpentry work in a cylindrical granary. Aside from acting as an opening, a door of such a granary is also used as a clamp fixing the two ends of the bamboo wall. Shown in Fig. 4.17, we can notice wooden nails used to fix the bamboo wall with the door frame. Both the door head and the sill are connected to two door jambs with dovetail joints. This types of joints are used to resist the pulling force.

Generally, door leaves are held by an outside door stick as a lock. This wooden stick is tightly fixed in the hole of the door frame. To open it, someone needs to use a hammer to knock the stick from the door frame. This process is accompanied by loud noises, considered to be a common and simple method of theft prevention.

There are generally three door-planks in a door (Fig. 4.20). Among them, the central piece is a narrow independent board. This design is a simple measure assumed to prevent against shrinkage and nevertheless seal the door. During the shrinkage process, gaps will occur in between these door planks. At this point owners could replace the original central piece with a wider one, thus ensuring the sealing of the door.

4.2.2.1.6 Mouse guard

Rats are a major threat to granaries. To prevent rats from entering granaries, the Yao people try to block any possible path for these

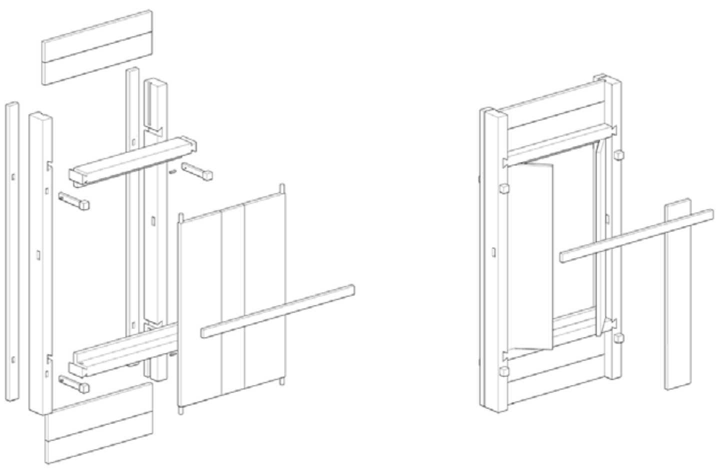


Fig. 4. 20 Construction detail of the door frame.

small animals to enter storerooms. Mouse guards were invented accordingly.

For cylindrical granaries, nearly all mouse guards are clay pots without bottoms. They are held in place by a simple method. At the height where the pot is intended to be fixed, the pillars are recessed in diameter in order to create a support area (Fig. 4.21). Then pots can be put on the pillars from their top ends. As a precautionary measure, the pillar's recession at the height of the pot is cut so wide that even expanding wood in the case of high humidity cannot affect the pot. Obviously, they had already been placed in this position in the construction process of the major framework, and they could not be moved away until broken. On the other hand, this also means that broken pots cannot be replaced by new ones unless the whole structure is taken apart.

Fig.4. 21 A damaged clay pot in a granary.

4.2.2.2 Cuboid granary

According to interviews with locals, people began to build wooden cuboid granaries in the 1970s. They believed this building technology was learned from Bouyei people. However, it can also be related to the introduction of the mechanical saw, which promoted the wide application of wooden planks.

Given the number of storerooms, the cuboid granaries of Dongmeng can be subdivided into one-room cuboid granaries and two-room cuboid granaries. Two-room cuboid granaries are the majority in this village. The following is based on a detailed measurement of a two-room cuboid granary (Fig. 4.22). The granary consists of a roof structure, a framework, walls, a floor, a ceiling, doors, and mouse guards (Fig. 4.23).

4.2.2.2.1 Framework

The main framework of the selected cuboid granary is assembled by six vertical pillars and three layers of tie-beams. An interesting finding is that there are three different types of joints applied in these three layers' connections (Fig. 4.24, 25). Lowest tie-beams are fixed to the pillars by wedges, while middle tie-beams are keyed to the pillars. The topmost tie-beams are connected to pillars in a unique way. The tops of pillars are recessed in diameter, and the top ends are housed in centrally cut holes prepared at longitudinal beams' outer ends. In transverse direction, the topmost transverse beams are round beams. They have cut notches perfectly fitting with the forked pillars' heads. Inserted into the forks, a stable connection of pillars, longitudinal beams, and transverse beams is ensured. With such joints, longitudinal beams can be removed independently

Fig.4. 22 The selected two-room cuboid granary.

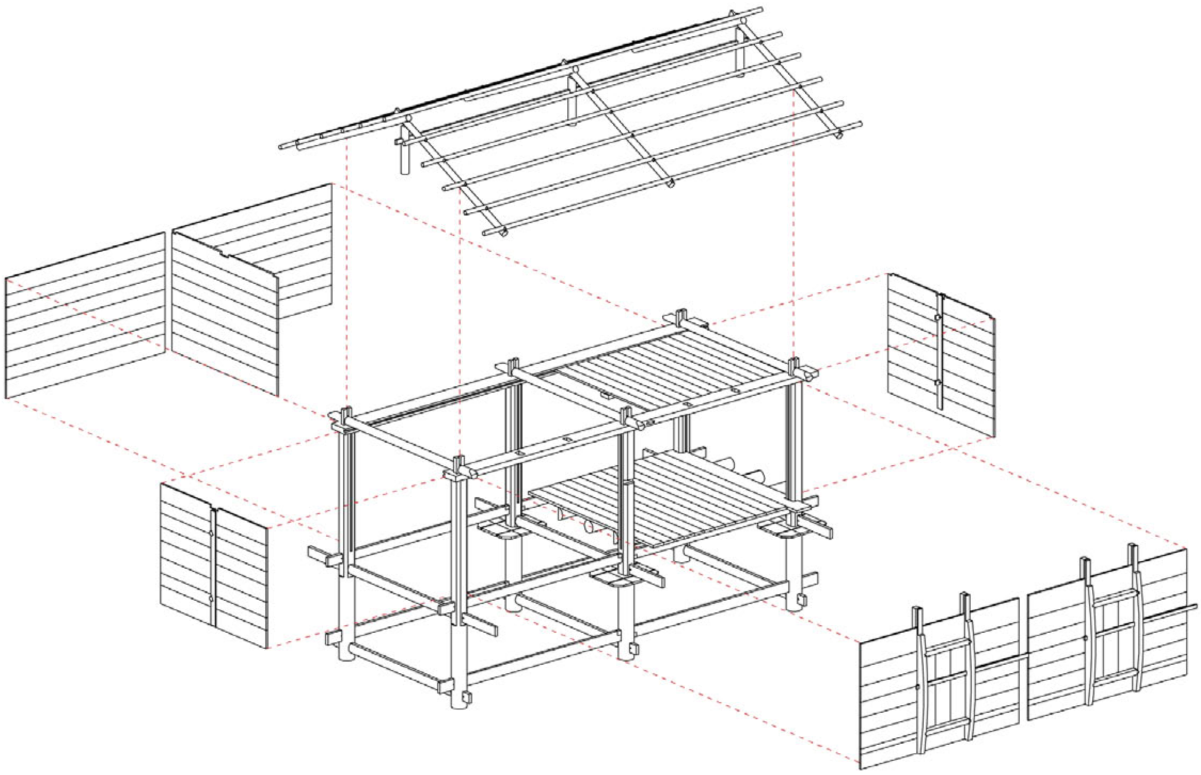


Fig.4. 23 The granary consists of a roof structure, a framework, walls, a floor, a ceiling, doors, and mouse guards.

from the main frame when it is necessary.

These details raise two questions:

i. Why did local people apply different joints for the different layers of tie-beams?

ii. Why did locals invent a moveable joint?

In a granary with a skeleton structure, inner pressure from the load of stacked grain is transferred from the wall to the framework. It raises a large side thrust. For this framework, tie-beams of the topmost layer and mid-layers are major members for resisting side thrust. Already the comparison of lowest layer and mid-layer gives clear indications. Keyed tenons resist better the pulling stress than do ordinary through tenon joints. I am convinced that locals have noticed the different force conditions in such kinds of granary structures. Thus, they use stronger joints in places that bear more thrust and use simpler and weaker joints in places that bear less thrust. This approach can be seen as a measure to find a balance between ensuring the stability of the whole structure and saving working time.

The special way of connecting the tie-beams and pillars is a noticeable feature of cuboid granaries. It provides a strong binding for pillars against thrust. What is more important, the upmost connection allows tie-beams to be moved up freely when lifting the

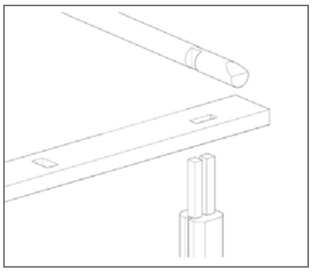
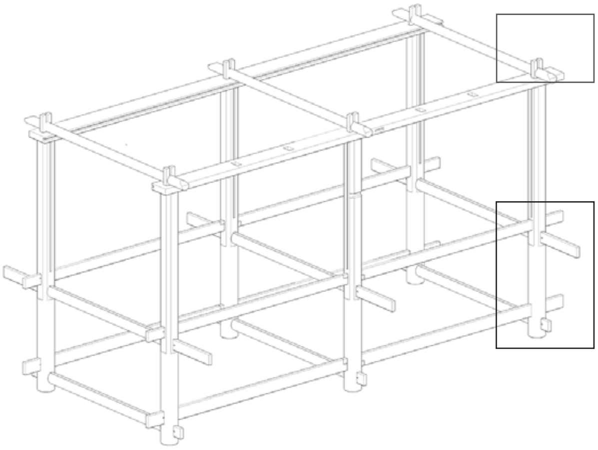


Fig.4.24



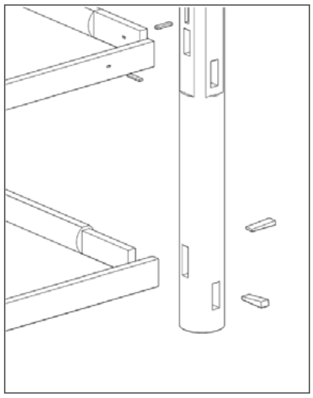


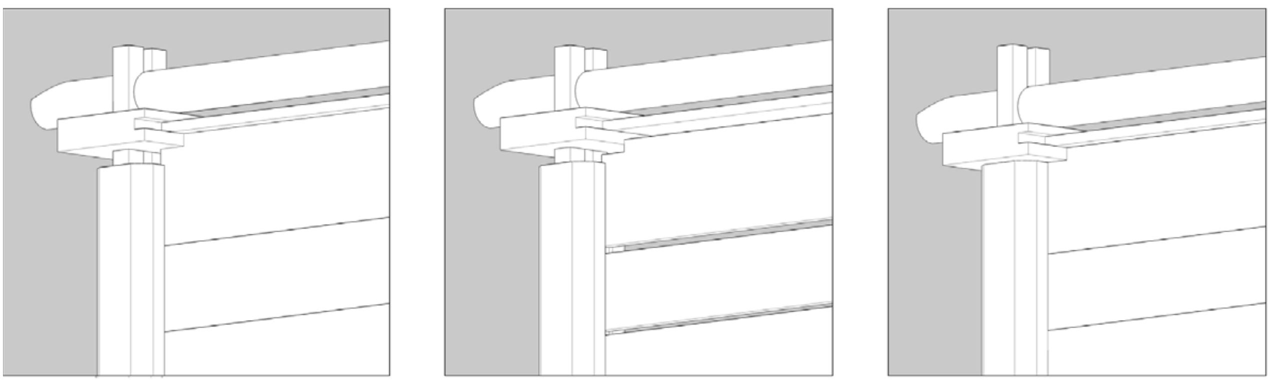
Fig.4.25

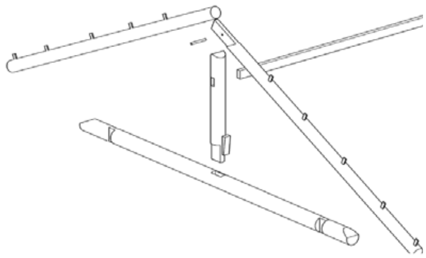
roof. This ability is related to the special building process of this type of granaries. In such a construction process, the framework of a granary is usually completed firstly. Wooden planks are then inserted into grooves of pillars to form walls with horizontal planks. The length of these planks should be slightly longer than the surface spacing between the two pillars; thus they can be held by grooves of pillars. Consequently, these planks are usually inserted into the frame in an inclined way. However, the last wall plank would be hard to insert into the frame in this way, since the space remaining between the upmost beam and the existing wall is too small. In this case, moveable topmost tie-beams would facilitate this process. Additionally, the final height of a wooden wall was to be “three fingers higher” (around 5 cm) than the top shoulders of the pillars (Fig. 4.26), according to Yao’s conventional building regulation. Due to the short drying duration of wooden components in this Yao village, the width reduction of wooden planks in their shrinkage process is more significant than in other regions. According to their experience, it would be around “three fingers” wide. In order to deal with this problem, the whole granary would be left empty for two to three years after it was assembled. During this period, the shrinkage process of the timbers of the granary would occur, with gaps appearing between wall planks. After two to three years, local carpenters would return to correct this problem. They would remove

Fig.4. 24 The joint of the topmost beams.

Fig.4. 25 The joints of the lower two layers of beams.

Fig.4. 26 Changes happened during the shrinkage process of the granary





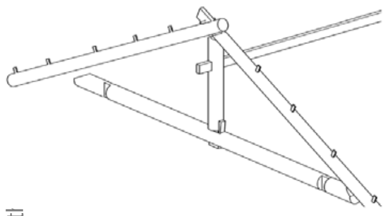


Fig.4. 27 Roof construction detail

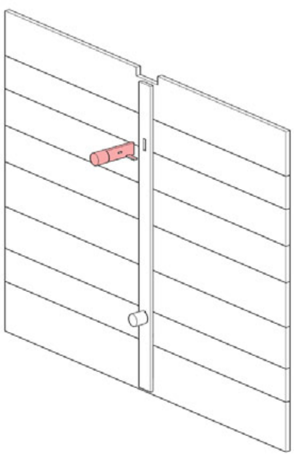


Fig.4. 28 Wall construction detail

the roof structure and kick the topmost tie-beams down along the tenons of the pillars. Moveable topmost tie-beams are necessary to produce perfectly sealed granary walls.

4.2.2.2.2 Roof

Cuboid granaries are mostly covered with tile roofs, which are heavier and more durable than are thatched roofs. The tile-making technology was introduced into this village in the late 1970s, following the introduction of the technology of wooden granaries.

The roof structure is a rather independent structure put on the main structure (Fig. 4.27). There are three trusses laid on the main framework for creating the main roof structure. The topmost transverse tie-beams also act as structural members of this roof structure. Short pillars defining the inclination of the roof are inserted into these transverse beams and jointed by a wedge. A thin stick is used to connect the three short pillars in longitudinal direction. Pairs of cross rafters connected with wooden nails are supported by these short pillars. Battens for hanging tiles are fixed to these rafters by wooden nails.

4.2.2.2.3 Wall

Walls of a cuboid granary are formed by horizontal wooden planks, which are held in grooves of the pillars. The average thickness of these planks is 3 cm. They are cut out from logs by circular saws.

In walls of the rear side and gable sides, wall planks are clamped by pairs of vertical wooden battens in the middle. These wooden battens are fixed to the wall boards by wooden nails (Fig. 4.28). They can be seen as a simple measure against the potential warping of these wooden planks. The main building material of wooden granaries is Masson pine. One unfavourable quality of Masson pine planks is that they tend to warp during the drying process much more than Chinese fir planks do. In addition, the inadequate drying process increases the possibility of warping these planks. For wooden granaries, when warping happened among wall planks, it would lead to leakage of stored grain. I believe that locals realized this risk after unfavourable experiences. The introduction of wooden battens should solve this problem.

4.2.2.2.4 Ceiling and Floor

Ceiling planks are housed in the grooves of the two topmost longitudinal beams. They were inserted into the main frame one by one from the gable side (Fig. 4.29). Similar to the floor fastening

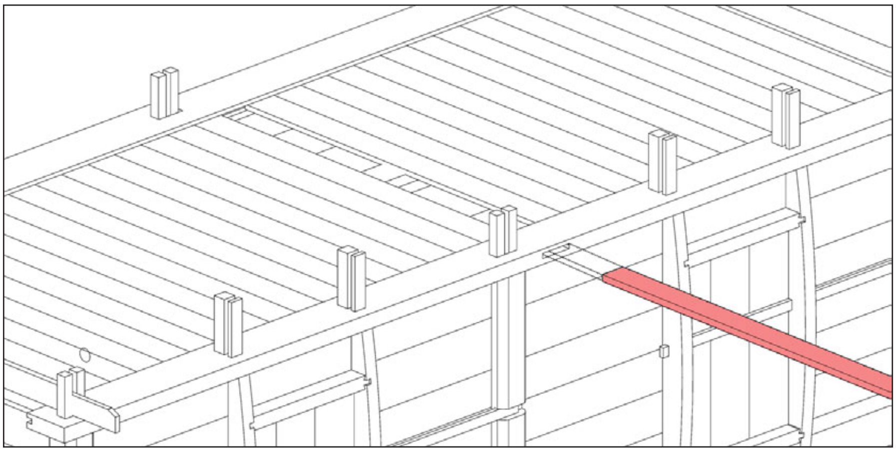


Fig.4. 29 The fastening method of the ceiling.

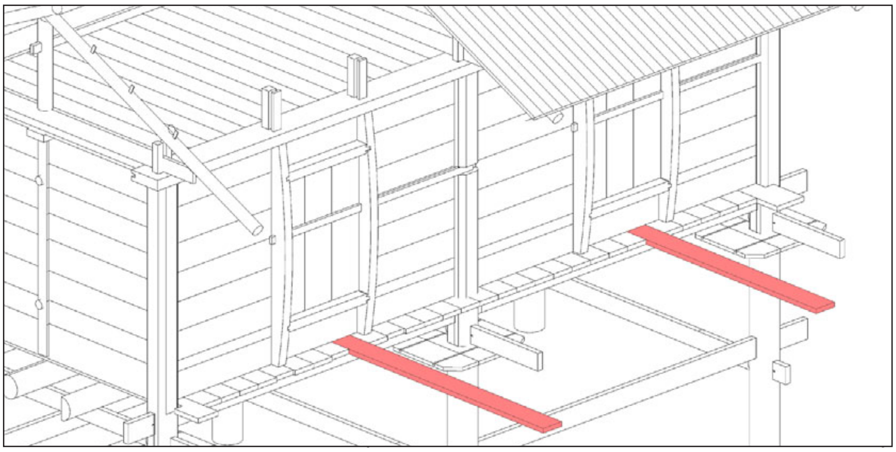


Fig.4. 30 The fastening method of the floor.

worked on the floorboards directly next to the pillars in a specific way. The outmost floorboards were recessed in their width in order to encompass the pillars and fit with the wall boards inside at the same time. The tapered floor board driven into the floor plane, at last, pressed the pillars as firm as possible against the resistance of the formerly mentioned wedge (Fig. 4.30).

Closer inspection allows one to notice another detail: Numbers of thin wooden blocks are inserted between the floor and carrying beams or joists beneath (Fig. 4.31). These blocks are expected to have been a remedial measure for shrinkage of beams. Due to the inadequate drying process of wooden beams and a heavy load from stored grain, these carrying beams usually sink severely. Meanwhile, the lowest planks of the walls are still held by grooves of pillars in their original positions. Thus, some gaps would occur between the edge of floorboards and wall planks during this process. Aiming at eliminating these gaps, thin wooden blocks were inserted between the floor and lower beams beneath as a remedy.

Fig.4. 31 Thin wooden blocks were inserted between the floor and lower beams beneath as a remedy measure.

4.2.2.2.5 Door

Based on a detailed investigation, it is clear that door frames are actually fixed in the lowest and topmost wall planks of the front wall in a granary. Thus, we can believe that these door frames

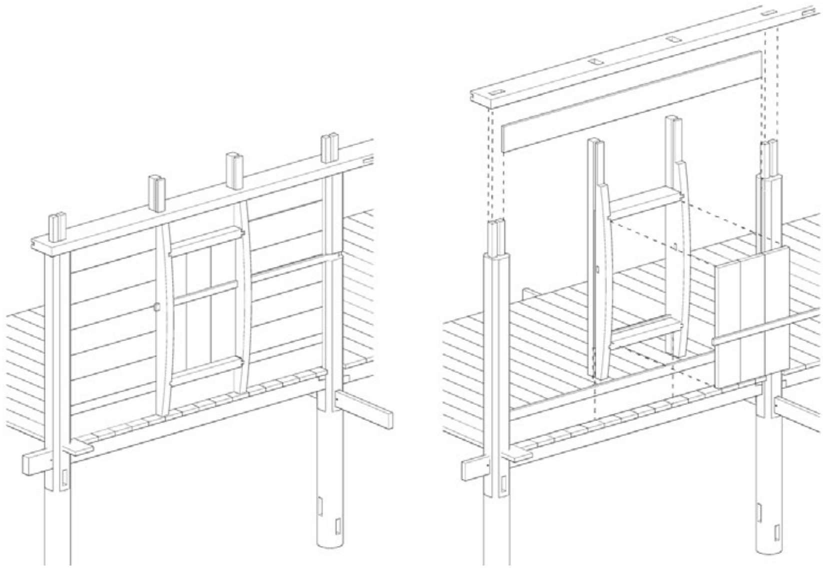


Fig.4. 32 Construction detail of the topmost beam and the door frame.

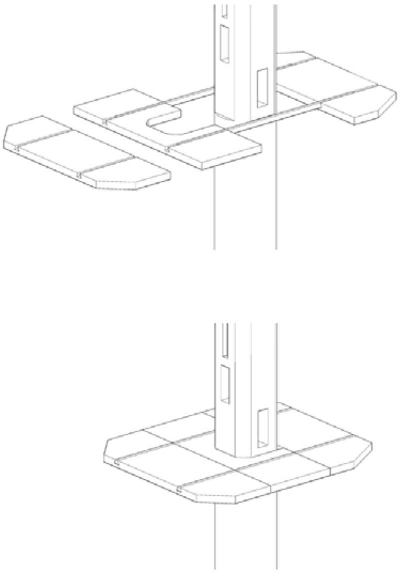


Fig.4. 33 Construction detail of a traditional wooden mouse guard.

Fig.4. 34 Thin aluminium sheets were wrapped on the upper parts of posts of the granary.

are inserted into the structure during the wall's construction. Considering the dropping of the lowest wall planks during shrinkage progress, the ends of door frames are shaped into forked openings, in order to facilitate the installation of thin wall planks in the wall, used to seal the wall (Fig. 4.32).

4.2.2.2.6 Mouse guard

Generally, mouse guards of cuboid granaries are square wooden slabs usually composed of three wooden planks. They are joined by two binding battens equipped with sliding dovetails (Fig. 4.33). This joining method, called "*Chuandai*"（穿带）, is mostly used for making wooden door leaves. Cutting long grooves with dovetail shape, a professional type of planes has to be used. This most probably was part of the "advanced" building technology imported from other places. In cuboid granaries, binding battens are used on the upside of these wooden mouse guards; thus, their downward side can be smooth. Locals believed that these smooth downward surfaces can prevent rats from climbing through mouse guards.

Compared with the clay-pot mouse guards of cylindrical granaries, wooden mouse guards are advantageous. If they were damaged or broken, they could be replaced easily without dismantling the whole structure. However, when wooden mouse guards are broken nowadays, more and more farmers turn to another "modern" type of mouse-proof method: wrapping the top of the pillars with thin aluminium sheets (Fig. 4.34).

4.2.3 Variant

A unique cuboid granary stands next to the drying place. According to locals, this granary was built in the 1970s. It was a community

granary during the People's Commune period (late-1950s the late-1970s). In that period, it was to be the granary storing all the harvests of the village (Fig. 4.35).

Fig.4. 35 A former community granary built during the People's commune period.

The special characteristics of this community granary are its surrounding veranda, overhanging brackets, *Xuanshan* (悬 山) [8] roof, and round stone mouse guards. Some of these characteristics are decorative, such as overhanging brackets (Fig. 4.36). Their complex forms are not so much due to structural requirement of supporting eaves but presumably as a means of decoration. Stone mouse guards are also used to imply impression and stability of this building. All of the characteristics sanctify this building and emphasize its importance. It is likely that carpenters wanted to give meaning to this granary: a treasury belonging to the whole village. By presenting this sacred architecture, local villagers wanted to show their respect to the new social system People's Commune period. However, considering to the volume of this building, it is too small to store enough food for all villagers to consume. This building cannot meet the demand to store a year's supply of rice.

8. Xuanshan（悬山）: It is a kind of hip roof, that signifies a high statue as building feature in Chinese traditional building regulations. `

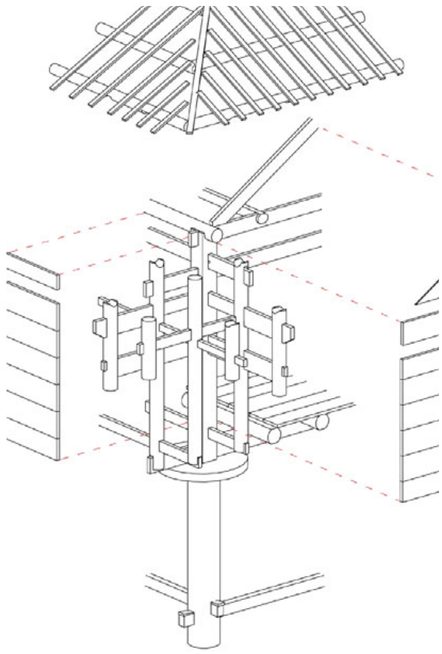


Fig.4. 36 Construction detail of an overhanging bracket.

4.2.4 Summary

By analysing different types of granaries, the above study reveals that different building technologies created different granaries in

Dongmeng. The study reveals the related influences promoting the change in building technology.

With the study on the history of the village, I suppose that the change of the building technology of the granary of Dongmeng is firstly related to the change of the living mode and the cultivation mode. Many features of the cylindrical granary imply that it is a kind of remain of shifting cultivation and non-sedentary living modes, such as the short-term construction period, the rough structure, and the reconstruction frequency. In comparison, one of the main advantages of the cuboid granary is its stability and durability. When Yao people began to settle their area in the 1950s, locals may initially have realized the importance of a stable granary from, which could effectively extend its service duration.

Another influencing factor for the change of the building technology might have been the species of the staple crop. When rice became one of the main staple crops, the requirements concerning granaries changed. The former woven bamboo wall was suited to store maize, but it was too rough for rice. The wooden wall became a good alternative. The planting of two main staple crops led to the requirement for the separation of the storerooms. A cuboid granary separated into two storerooms solved this problem.

Although textual records are lacking, I believe that one important influencing factor is the introduction of new carpentry tools and the "advanced" building technology, which might have accompanied with the import of the rice planting technology beginning in the 1950s. According to the official record, very few iron tools were used in the Yao villages of this region. They were quite simple and rough (黔南布依族苗族自治州地方志编纂委员会, 1993). Their simple structure and the wide application of the tied joints and simple housing joints in their construction imply that cylindrical granaries were traditionally built with limited simple tools. Compared with the cylindrical granary, the types of joints of cuboid granaries increased, and some types of joints could only be completed only by complex and professional tools, such as the Chuandai.

Finally, the concept of a granary could have been important for the building technology of the granary. The example of the public granary of the People's Commune period shows that a then-perceived symbolic meaning of the granary could change the appearance of the granary. This led to a subsequent change of building technology.

4.3 Dong villages: Dengcen

Dengcen is a Dong village located in a valley in the mountainous region of southeast Guizhou. Dengcen is a mid-size Dong village housing a scale of 157 families (655 people) until 2013 (Housing and Urban-Rural Development of Liping Municipality, 2013) (Fig 4. 37;38).

4.3.1 Village, dwelling and granary

Dengcen is located at the junction of two rivers. One of the two rivers is Dimeng River, which is the major river of this valley area. The main part of the village was built on a slow slope along the eastern bank of Dimeng River. The eastern bank of the River, which is a flatter area, is used for the terraced paddy fields of the village. There are some other fragmented and small paddy fields scattered in the northern mountainous area. The distances between rice fields and the village could be extremely far, taking perhaps one to two hours to reach. Generally, sticky rice fields are created close to the village, while normal rice fields are farther away. Since the 1950s, the planting area of normal rice was continually expanding due to the "*Nuo Gai Xian*(糯 改 籼)[9]" policy. As a result, the total planting area of normal rice of whole Liping region[10] accounted for 70% of the total cultivated area in 1958–1959 (《黎平县志》编纂委员会 , 1989, p. 124).

Aiming to save more farmlands for planting rice, the residential buildings of the village are arranged in an extremely dense manner. The eaves of neighbouring houses can even touch each other. Most of traditional Dong buildings were two-story or three-story wooden

9. Nuo Gai Xian(糯 改 籼): Its literal meaning is changing sticky rice into normal rice. This policy aimed to reduce the proportion of sticky rice planting area .

10.Dengcen is a village belonging to Liping town.

Fig.4. 37 Dengcen village, Liping, Guizhou.

Fig.4. 38 The satellite map of Dengcen.

buildings covered with tile roofs. According to my investigation, most of the families of this village own open fireplaces in their living rooms, apart from ovens in kitchens (Fig. 4.39). These fireplaces were initially built for both cooking and heating in the past. Over the past 50 years, the cooking function was gradually separated from the fireplaces in most Dong houses, due to fire prevention requirements. However, open fireplaces are still kept in many local houses as a cultural symbol and for heating. In addition, braziers are commonly used in the rest areas of the house. All these heating factors lead to the increased possibilities of fire disaster. The high-density building environment of Dong villages allows fire to spread easily, quite often causing the destruction of a whole village. Such tragic accidents have occurred frequently among Dong villages in the past (《三江侗族自治县概况》编写组, 2008, p. 280).

Aiming to prevent serious fire disaster, several measures were developed in Dong villages. First of all, the Dong people formulated a series of *Dong Kuan*(侗款)[11] related to fire-prevention (徐晓光, 2016, p. 77). A regulation of Dong Kuan of some villages demands that when a family causes large scale fire disaster in a village, they must move out of this village as punishment (Ibid.). In Dengcen, one fire-proof regulation is that "logs and wooden branches should not be laid along the main roads and under the drum tower". This regulation forces most villagers to keep logs and wooden branches outside the village. Some Dong villages even had self-organized patrols to alert people of the need for fire prevention in the past (徐晓光, 2016, p. 80). Secondly, they set up a series of pools between buildings for fire prevention, as shown in Fig. 4.40. When a building catches fire, people can use water from these ponds to extinguish the fire in time, thus preventing it from spreading. Apart from this these uses, ponds are mostly used for fish stock and duck habitat.

However, these thoughtful measures could not completely prevent the occurrence of fires. As mentioned before, once fire occurs in

11. Dong kuan (侗款) is a kind of customary laws used in Dong communities. They were developed to rule a wide range of daily activates of members in Dong villages. The system of Dong Kuan contains primitive ideas of modern rule of law. It is still used in some Dong villages until now.


Fig.4.39


Fig.4.40

Fig.4. 39 An open-fireplace on the centre of the living room in an ordinary Dong dwelling.

Fig.4. 40 A pool for fire prevent in Dengcen.

a house surrounded by neighbouring houses in high density, as in Dengcen, all adjacent buildings are likely to burn. The worst thing in such an accident is that stored food is also burnt. This loss causes famine and even death, especially for remote mountainous villages. As a result, many Dong villages insisted on building their granaries in places far from their wooden dwellings, in order to protect them from being affected by fire. This is also common sense in village layout among some other ethnic groups.

In Dengcen, locals developed a smart idea for arranging their granaries. In the north of the residential area, there used to be a small valley and a creek running through it. Due to lack of sunshine, this narrow valley was neither suitable for building dwelling houses nor for planting rice. Such a location is not a problem for granaries (Fig. 4.41), however. Locals reformed this isolated valley area into a series of terraces, similar to those for planting rice. The creek flows through those terraces, forming a series of ponds around 30 cm deep (Fig 4.42). Drain holes were made in dams between these ponds, thus ensuring that fresh water can continually flow through all the ponds. This keeps the water of these ponds clean. Local people built their wooden granaries in these ponds. They believe this location offers effective fire prevention. Moreover, these ponds could be used for duck raising.

However, those measures are unable to protect against arson. In the 1940s, a group of bandits burnt down nearly all granaries by setting fire to them. Due to this arson , most of the existing granaries of Dengcen were built after the 1950s. Only a few ancient granaries are persevered. I introduce one of them as a case study.

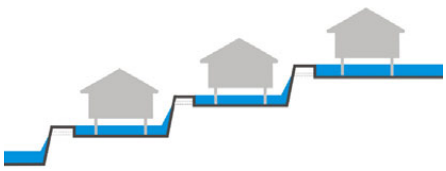


Fig.4. 41 The small valley with numbers of granaries.

Fig.4. 42 Diagrammatic section of the terraces in the valley.


Fig.4.43


Fig.4.44

Fig.4. 43 A granary without drying rack

Fig.4. 44 A granary with drying racks

4.3.2 Granary and its construction

In Dengcen, traditional wooden granaries could be classified into two categories: granaries with drying racks and granaries without drying racks (Fig 4.43; 44).

Due to the ongoing promotion of ordinary rice planting policy since the 1950s, the planting area of ordinary rice is already larger than that of sticky rice. However, local people still keep the planting tradition of sticky rice, and they regard it as their staple food. Nearly all families plant both sticky rice and ordinary rice nowadays.

The drying processes of sticky rice and ordinary rice are handled quite differently in Dong villages. Sticky rice needs to be hanged in drying racks, and ordinary rice is usually dried on the ground. Locals recalled that independent drying racks were used in the past when they planted more sticky rice than they do nowadays. Such independent drying racks can still be found in many Miao and Dong villages in South Guizhou.

Fig.4. 45 Concrete platforms were built for drying ordinary rice

However, due to the increase of the planting areas dedicated to ordinary rice, independent drying racks vanished in this village. Instead, people built concrete platforms for drying ordinary rice (Fig4.45). The main concrete road of the village is also used for drying ordinary rice.

The majority of the granaries built after the big fire of the 1940s were erected without combined drying racks; few are still equipped with drying racks.

Most of granaries in Dengcen consist of more than one storage unit. This multiplicity of units can be related to the Dengcen people's habit of growing two type of rice. In addition, this feature might also be related to the local extended-family pattern popular in the Dong area in past. In the traditional extended family organizations of Dong villages, parents usually live with their several adult children's families under a single roof. Nevertheless, each small family has a certain degree of independence. This arrangement might have promoted big extended families to build big granaries with several storage units, so each family could own their own storage units. The number of storage units belonging to one family can vary from one to several.

The numbers of storage units of granaries varies from one to eight or more. However, these storage units are mostly of similar size. Locals believe that the average capacity of these storage units is around 5,000 kg. According to the statistics of per capita arable land and the scale of a common small Dong family, we can speculate that the average amount of actually stored grain in a normal storage unit is much less than this capacity .

4.3.2.1 A granary without drying racks

A two-storey granary with seven storage units, probably built in the 19th century, was select for detailed measurement and analysis (Fig4.46;47). This granary is one of the few granaries preserved after the fires of the 1940s. This granary is shared by seven families now.

This granary consists of the main framework, a separated roof structure, exterior wooden walls, inner partitions, ceilings, floors, and doors(Fig. 4.50). There is an additional wooden fence added to the outside the frontage of the granary, aiming to protect the stored rice against theft.

According to the present surrounding situation, this granary seems to have stood in a pond in the past, just as the other granaries of this village. The average height from the water level of the pond


Fig.4.46

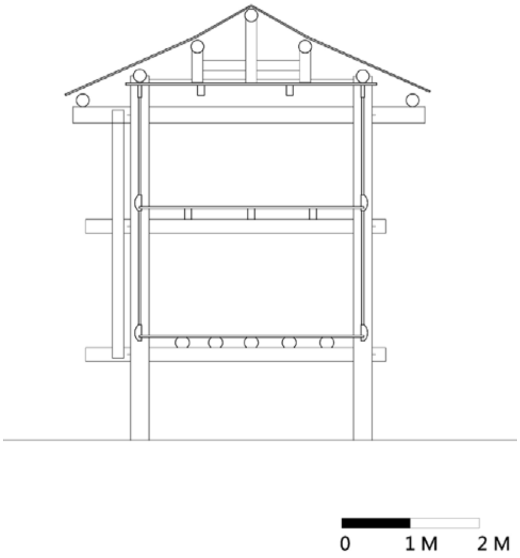


Fig.4. 46 A selected two-storey granary

Fig.4. 47 The section of the granary

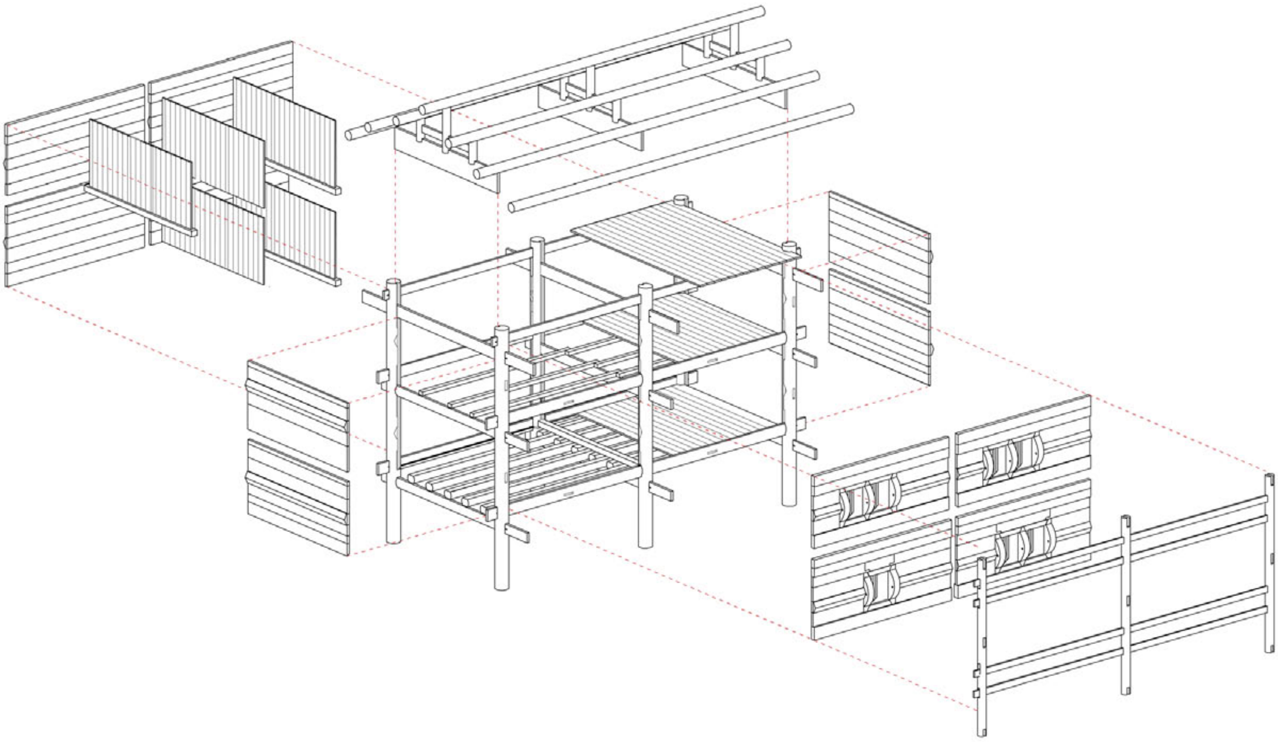


Fig.4. 48 The granary consists of the main framework, a separated roof structure, exterior wooden walls, inner partitions, ceilings, floors, and doors

to the elevated floor of the granary is around 1.5 meters. Thus, to get into the granary, a ladder is necessary. The spaces beneath the granaries are mainly applied for storing trunks and branches or even coffins. They cannot be stored in the village due to fire-prevention considerations. Some locals fenced off the area directly beneath their granaries to keep ducks.

4.3.2.1.1 Framework

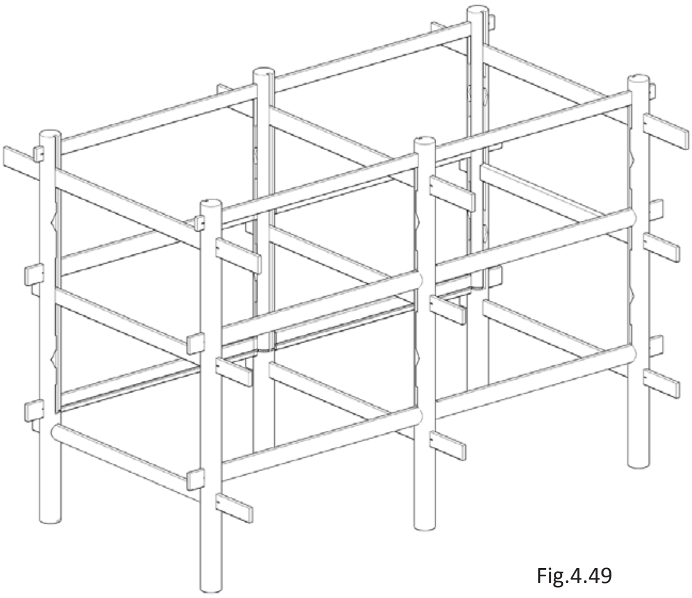


Fig.4.49

Fig.4.50

Fig.4. 49 The main framework of the granary

Fig.4. 50 The special keyed joint

The main framework of the granary looks quite simple (Fig4.49). It was assembled by six pillars and three layers of tie-beams. Based on study of the granary's details, longitudinal tie-beams were spliced in the middle pillars. This structure suggests that this granary was built following the Chuandou construction method. The central and lower transverse tie-beams support joists; in other words, they carry all load from stored grain in this granary. This might be the reason that the lower transverse beams were named *Qing Jing Fang* (千斤枋)[12].

12. Qing Jing Fang (千斤枋): It literally means that beam which can carry one thousand kilogram load.

Although this frame looks simple, further analysis shows some interesting details: First of all, the centre, mid, and lower transverse tie-beams of this frame carry nearly all the load from the stored grain, while the longitudinal tie-beams seem to act only as anchoring pillars. This design is uncommon. Longitudinal tie-beams in wooden granaries were generally load-bearing beams in many other areas, such as Gaoding and Dongmeng. Second, cross sections of the main bodies of tie-beams are carefully carved into approximately semi-circular shapes. Finally, a special kind of keyed joint with semi-circular shapes is used for fixing the frame (Fig. 4.50).

What would be the consideration behind these detailed designs? To answer these questions, some further studies of details were carried on.

i. Special longitudinal tie-beams

In Dengcen, longitudinal tie-beams of many wooden granaries are not load-bearing members. This selected case study presents such an example. In wooden granaries with the skeleton structures of some other regions, longitudinal tie-beams usually play the same

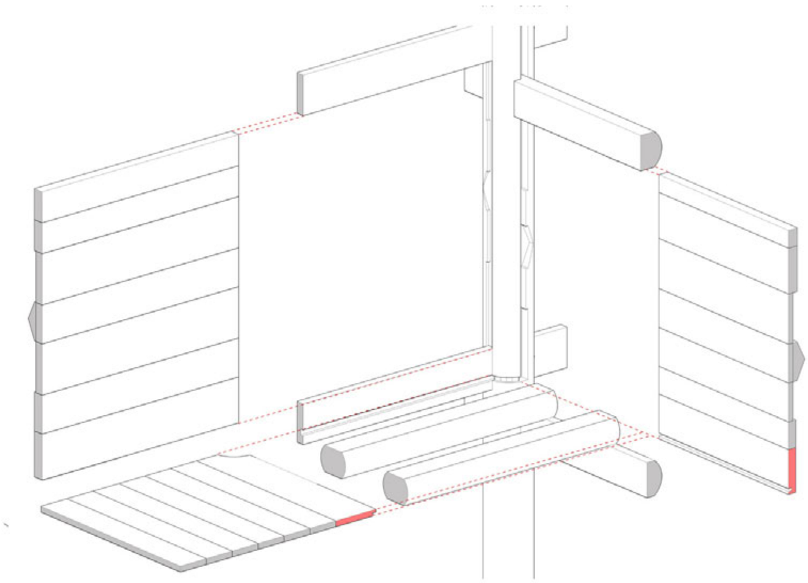


Fig.4. 51 Construction detail of the floor and beams

role as joists. Carpenters thus can usually save at least two more wooden joists in building a granary. However, the carpenters of Dengcen dealt with this problem in a contrasting way.

From further analysis of the relationship between floor planks, joists, and longitudinal tie-beams in this granary, we realize that groove was cut into the inside surface of each longitudinal tie-beam. All floor planks are housed with their ends in their grooves (Fig. 4.51). Due to the limited depths of these grooves, they can hardly help carrying any load putting on the floor. Therefore, carpenters needed to add more floor joists to distribute the load resting on the floor planks. In this case, carpenters installed five joists in the lowest floor. In contrast, in selected cases of the Dong village Gaoding, only two or three joists are used in similar transverse column spacing.

Despite its added costs in terms of material and labour, one major advantage of this detail is avoiding the exposure of floor planks' end grain to the outside. Apart from aesthetic consideration, the design of this detail mainly aims to protect these planks' ends from rain damage. Additionally, it can also prevent the occurrence of gaps between walls and floor. This is a common structural deformation problem in granaries, causing loss of grain.

ii. Beams with special forms

The central and lower tie-beams of this frame have the same special characteristic: cross sections of these tie-beams are semi-elliptical shapes, while their ends recessed to tenons were shaped into smaller rectangular sections. The bulging surfaces of these tie-beams present strengthens and stabilization of the frame. By investing sections of these tie-beams, the processing method can be revealed. It is assumed that carpenters firstly split a log into three uneven parts along its longitudinal direction: two equal

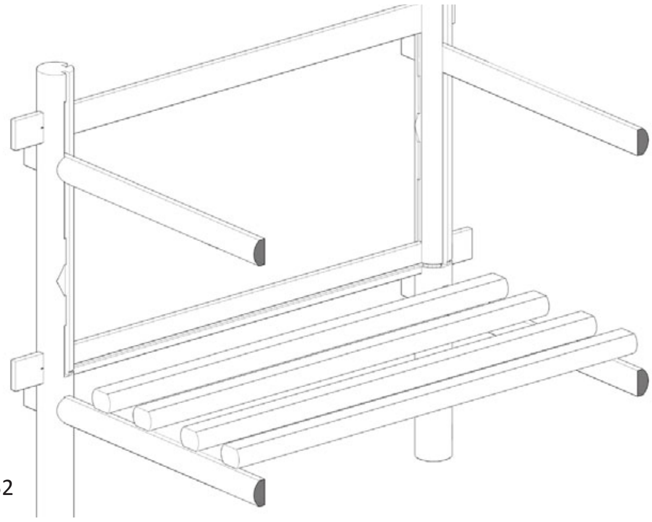


Fig.4.52

Fig.4.54

Fig.4.52 Sections of tie-beams are semielliptical shapes

Fig.4. 54 The connecting way of the pillar and beams

half-logs and one central part with the ring heart (Fig. 4.52;53). Carpenters then cut the upper and lower sides of the two half-logs to form main bodies of the tie-beams of the granary. This treatment brings an important advantage: shakes in the two half-logs can be insignificant or eliminated by taking out the heart part of the log. This is good for the stability of the whole framework. However, this treatment requires the use of the larger-diameter logs. For example, the lower longitudinal tie-beams of this study case has a beam height of 23 cm. For making such a beam with a semi-elliptical shape, the diameter of the original log should reach 31 cm at least. However, an important change in the recently built granaries of Dengcen is the disappearance of beams with semi-elliptical sections. This disappearance can be related to the general decrease of logs' dimensions after the 1960s.

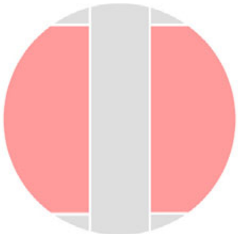


Fig.4. 53 Carpenters cut the upper and lower sides of the two half-logs to form main bodies of the tie-beams of the granary.

However, such detailed design raised for local carpenters the question of how to deal with the connecting part of tie-beams and pillars both having no flat surface. Local carpenters then shaped the beams' ends to fit perfectly the convex surfaces of the pillars (Fig. 4.54). This measure can prevent exposure of end grain wood shoulders to the outside, thus protecting the beams from rain damage.

iii. Keyed joint

Usually keyed tenons are executed by installing the key behind the pillar. In granaries of Dengcen, a special type of keyed joints is widely used to connect the pillars and beams (Fig. 4.55). Shown in Fig. 4.50, keys were inserted into specifically prepared notches in pillars. During the erection process, these keys are treated ordinarily. Only when shrinkage process of all wooden components of the granaries slowed down did carpenters cut off the exposed parts of the keys.

To shape such features in the building, carpenters added steps . One

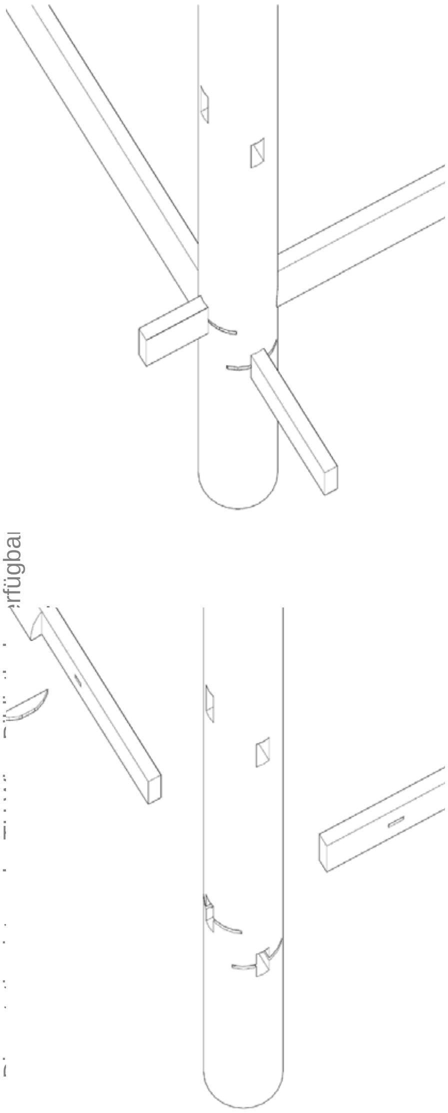


Fig 4. 55 Construction detail of the special keyed joints.

Fig 4. 56 The construction process of installing wall planks into the framework of the granary.

is a wooden protection measure, the other has purely mechanical reason. If the key is hidden entirely in the pillar it is better protected against rain and against mechanical damage, as there exist no protecting ends. If the beam suffers pulling stress, the tenon is pressed against the key. Executed in this way, the key is pressed along a length of approximately 10 cm against the pillar, in contrast to the otherwise only punctual contact surface of key on pillars. Sometimes, people would even build an additional small roof to protect the exposed tenon.

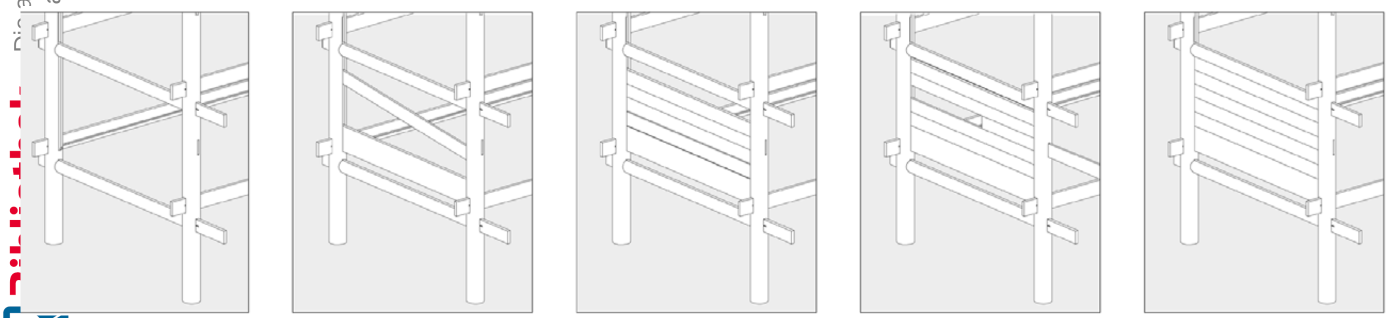
4.3.2.1.2 Wall

Sealing is the most concerning problem in the wall construction of a granary. Thus, local carpenters developed a series of building methods and details to ensure the sealing performance of granaries.

In Dong villages, the walls of the granaries are formed by horizontal wooden planks. According to local carpenter Wu Longyi, these wall planks of granaries are actually not strictly rectangle. Since local carpenters want to maximize the output of the available timber in most cases, they usually preserved original outlines of logs when sawing them into planks. As the original outline of a log cut lengthwise is actually trapezoidal, nearly all wall planks of this area have one end slightly smaller than the opposite end. This difference is difficult for untrained eyes to realize, however. For locals, such planks without parallel edges could be directly used in the dwelling construction, but not for the granary construction.

Local carpenters developed a specialized building process, in order to seal walls with such trapezoidal shaped boards in a granary construction. At the beginning, they needed to identify which ends of these wooden planks were smaller. Then, each plank was installed into grooves of the framework such that the bigger end lays on the smaller end of the lower plank in alternating order. In this way, the gaps between planks could be minimized. A gap was then left in the wall due to the height limitations for inserting planks obliquely.

Study of the building's details shows that local carpenters had already dug out through-mortises on front pillars during the components shaping process (Fig. 4.56). Each piece of wall



corresponds to through-mortises on one side. These pre-made holes would allow the last planks to be knocked into the frame from the outside. Given the shrinkage problem of the wall planks, the last plank is shaped into one end narrower in most cases. The width of the narrow end should be roughly equal to the width of the remaining gap in the wall. Then, part of the last plank would be inserted to fill the gap of the wall by kicking the narrower end of the plank into the frame. Then the carpenters would leave the building alone for around one month. After one month, the shrinkage progress would cause the gap enlarge slightly. The carpenters use mallets to knock the last plank into the frame completely. Finally the rest of the wall planks are fastened. This approach ensures sealed walls aiming to ensure the safety of the stored cereal.

Apart from details related to sealing, two more unique qualities are observed in the local wall construction. They are uncommon in other Dong regions. Additional horizontal members are inserted in the middle of each wall. They are long, slightly tapered battens pushed from outside into prepared holes in the pillars. Another detail is the application of planks with different thickness in the same walls (Fig. 4.57).

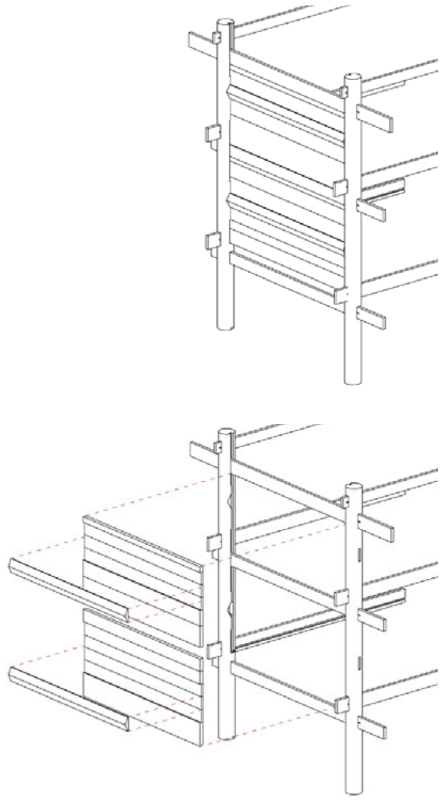


Fig.4. 57 Wall construction detail

The function of these details can be related to lateral thrust on the walls, as stored grain was mostly stacked directly on the granary floor, thus not only the floor, but also the walls would bear the pressure caused by the grain heap. In this case, the amount of the lateral thrust pressing on the wall relates to the load of the grain heap. The bottom of the wall suffers more lateral thrust than does the upper part. This difference could cause the deformation of the lowest planks in the walls, always associated with the threat of losing grain. In the section of thicker wall planks is the most common solution for reinforcement in order to prevent such losses. For economic reasons, the upper parts of wall bearing less thrust could be constructed with thinner planks. I suppose that local carpenters accordingly decided to apply planks of various thickness in the wall construction and add horizontal members for reinforcing walls where they thought they might be necessary.

According to my investigation, one simpler method against the deformation of the lowest wall plank was applied in some recent granaries: adding nails on the joists to prevent the lowest plank to be pushed outwards (Fig. 4.58). The main consideration behind this measure is to prevent gaps arising between vertical wall planks and the floor beneath.

Fig.4. 58 Wooden nails were added at the ends of the floor beams.

4.3.2.1.3 Roof

In general, roof structures are separate from main frameworks among the majority of granaries in Dengcen. In this selected case, the roof consists of several layers: roof structure, purlins, rafters, and tile covering (Fig. 4.59). The roof structure itself is assembled by three identical simple wooden frames. Each of them rests on a wooden plank inserted in grooves cut into the topmost ends of the pillars. A study of details shows that the planks are inserted but not fixed in the pillars. This means the whole roof structure can be easily removed when there is a need for maintenance.

Fig.4. 60 Adjoining eaves of these granaries touch each other

For supporting overhanging eaves, the topmost tie-beams of the main frame are also involved as suppers of the eave purlins. The cantilever distances of eaves are around 0.9–1 meters. Under a local rainy climate, such a distance cannot fully protect the vertical wall surfaces of the granary. However, the dense setup of the granaries balanced this disadvantage as the adjoining eaves of these granaries could even touch each other (Fig. 4.60). This ensures that major parts of vertical walls can be protected. However, for these two-story granaries, this is not enough. Locals had to try different ways to protect wooden walls and extended components of these granaries. Some people would thus add additional roofs at half the height of the walls.

4.3.2.1.4 Ceiling and floor

Aiming at sealing floors of the granary, wooden floor planks are connected to each other through tongue and groove joints. Apart from these connections, local carpenters also controlled forward-thinking the shrinkage problem of these wooden planks and

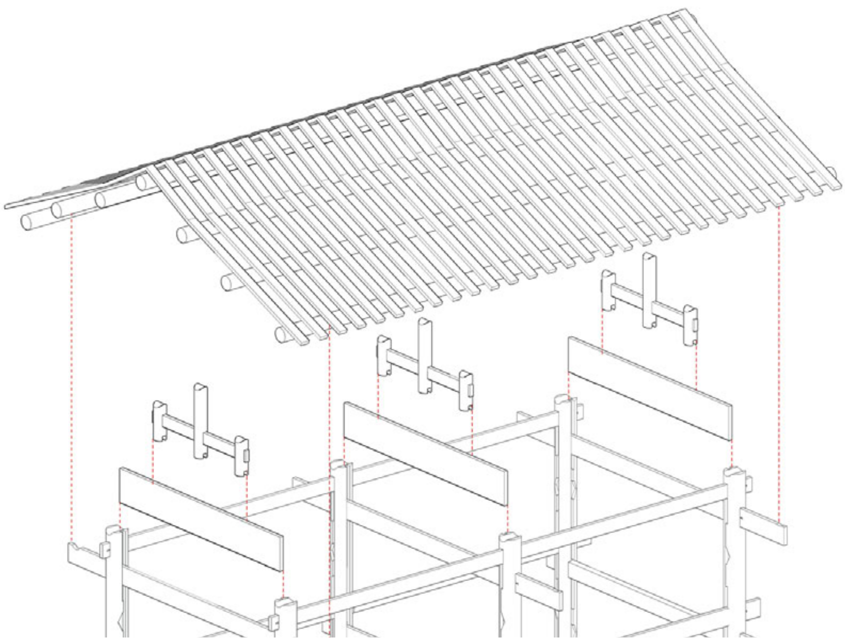


Fig.4. 59 The roof consists of several layers: roof structure, purlins, rafters, and tile covering.

potential risks of the granary. Similar to the Yao granary mentioned in the last section, a narrow plank with a narrower end is used in each floor in this granary for fastening the floor plank as a whole. In respect to the shrinkage problem, kicking these narrow planks into the floors should be done within a month after the completion of the main frame. To push these narrow planks into floors, through-mortises should be cut into the front of longitudinal beams in advance Fig. 4.61.

Compared with the floor system, the topmost ceiling system is simpler. A tongue and groove joint is not used in the ceiling of this granary. Under the load of the roof, two purlins are used to squeeze the ends of the ceiling boards between purlins and supporting longitudinal tie-beams. This measure aims to tightly fix ceiling planks with the main frame.

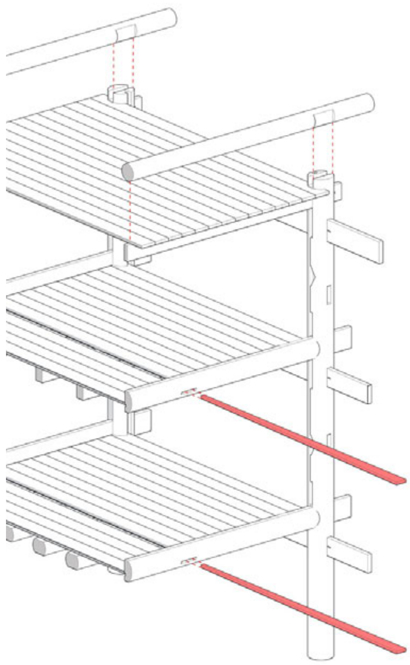


Fig.4. 61 The fastening method of the floors in Dengcen

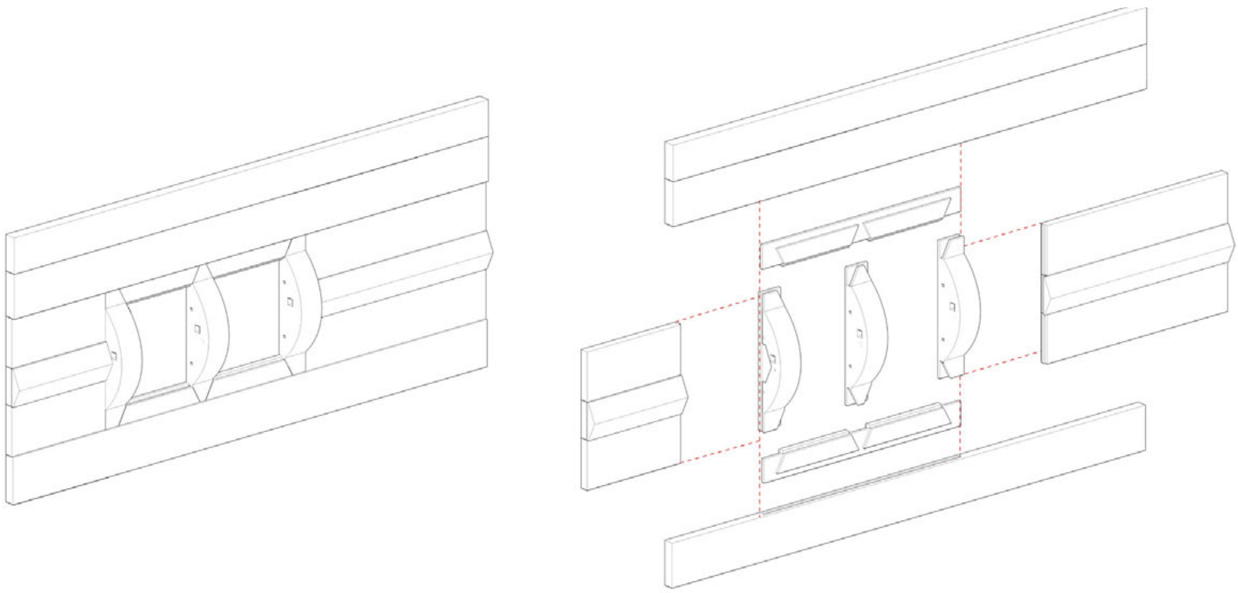
4.3.2.1.5 Door

Similar to other regions, doors are the most complex and detailed components of the whole granary. Especially in Dengcen, carpenters not only needed to consider the security problem but also prevent potential rain damage.

Due to the special spatial division of local granaries, connected double doors are widely applied in Dengcen. The following description is based on field study and analysis of details of a connected double door in this granary (Fig. 4.62).

The door frame consists of horizontal door sills and vertical door posts. Being inserted into the prepared grooves in nearby wall planks, doorsills combine the whole door frame with the wall. Door posts are joined with doorsills with forked ends. All these

Fig.4. 62 Door construction detail



components have complex shapes. They needed to be designed and executed precisely and skilfully.

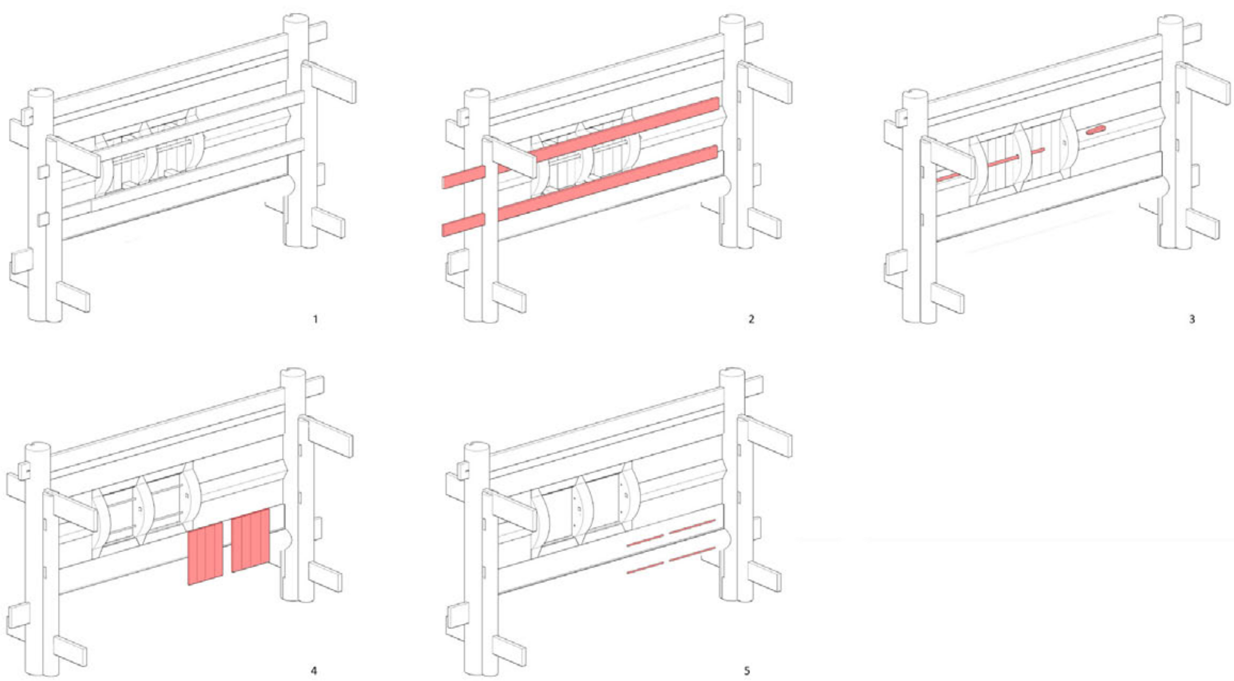
The door leaves are independent of the door frames. In ordinary cases, a door leaf is fixed by two inner sticks and one outer horizontal stick. These sticks are inserted into the door frames.

There is one more mentionable component in the door system of Dengcen area: fences, which rested on overhanging beams. They appeared most often in old granaries. In these granaries doors are fixed from outside with extra wooden blocks between the fences and door leaves, apart from locks. These fences are used as an additional reinforcement to act against the inner thrust of the stored grain. It is also suggested that these fences could provide additional protection for the granaries in the past.

To open a door of this kind, one needs first to remove the horizontal members from the fence and then take a hammer or something like a hammer to kick out the wedges, applied to fix horizontal sticks holding the door (Fig. 4.63). Only then can the horizontal sticks and the door leaves be removed.

Concerning the complexity of the door systems in local granaries, we should not ignore one necessary condition: the thickness of these wooden components. They are generally larger than are ordinary granaries of some other ethnic regions in Guizhou. For instance, if door sills should be tenoned into the grooves of the wall planks, these had to be 5 cm thick, considering the necessary shed.

Fig. 4. 63 The process of opening a granary



The average thickness of wall planks of Yao granaries is 3 cm. This thickness would be insufficient to produce similar features. Such a difference between Dong and Yao villages is inseparable from the local timber resources. This difference may also suggest that local rich timber resources also contribute to unique building technology development in Dong area.

4.3.2.1.6 Remarks

The above studies have indicated that many details of this granary were contributed to prevent the exposure of cross sections of wooden components and protruding members, such as the special design of longitudinal beams and the special design of keyed joints. I would like to suppose that the main principle of these designs is to protect wooden components from rain damage. Under the local humid weather, it is not surprising that such an idea is quite important for prolonging the service life of local granaries. In addition, the use of two-storey high granaries with single layers of roof in Dengcen might also make carpenters more aware of the problem of rain damage.

4.3.2.2 A granary with drying racks

Few granaries with drying racks persist in Dengcen. Granaries with drying racks are mostly assembled of two parts: the storage core and attached drying racks. The construction of the storage core part is almost the same as ordinary granaries without drying racks. Thus, this section focuses on discussing the relationship between the inner storage core and outer drying racks. According to the position of drying racks in a granary, there are two types of granaries with drying racks: front-drying racks granaries and enclosed-drying racks granaries (Fig. 4.64; 65).


Fig.4.64


Fig.4.65

Fig.4. 64 A front-drying-racks granary

Fig.4. 65 An enclosed-drying-racks granary

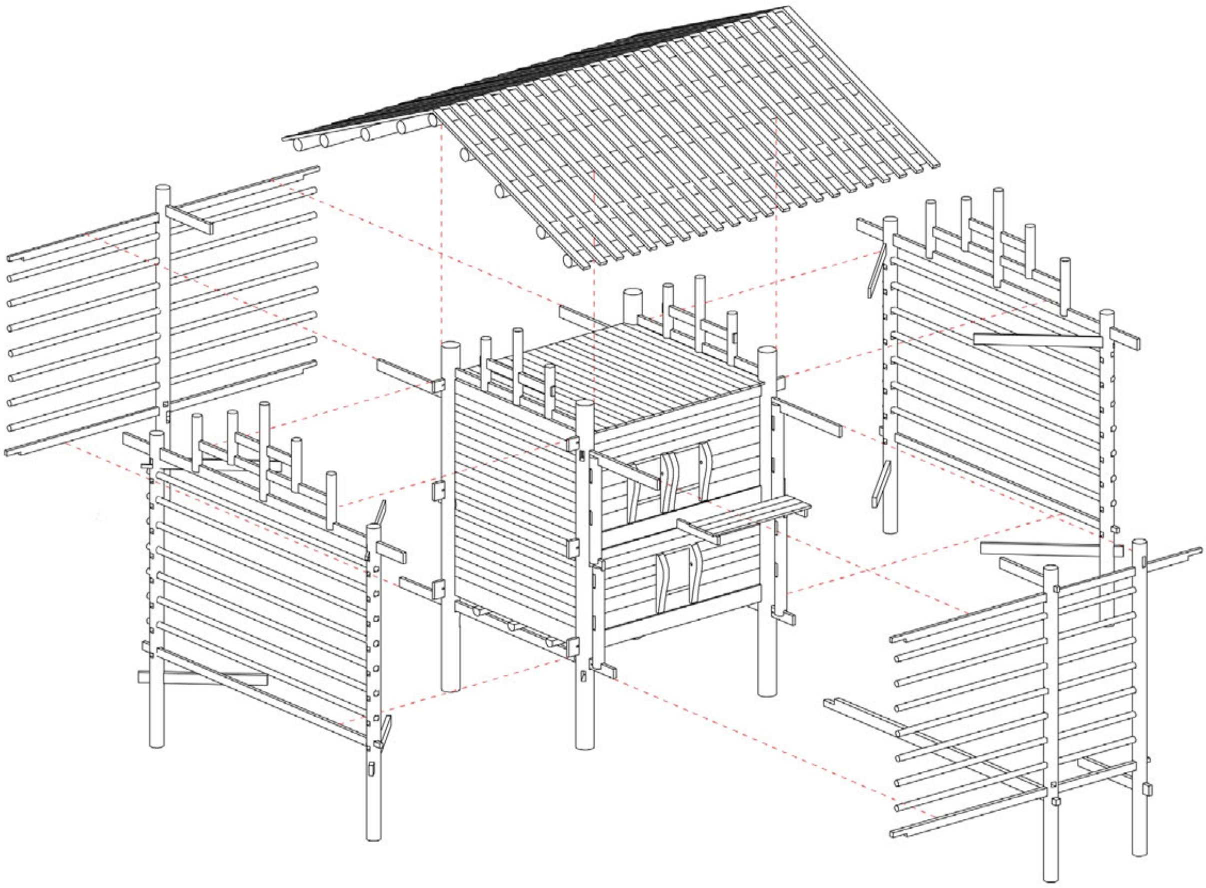


Fig.4. 66 The granary is assembled of two parts: the storage core and attached drying racks.

The selected granary is enclosed by drying racks on all four sides. There is a surrounding passage between the storage core and the drying racks. This passage is mainly used for hanging bundled rice stalks under the roof. It also keeps a certain distance between storage units and drying racks, promoting air flow between them.

In studying tenon types of the selected granary, however, we can realize that its drying racks are a comparatively independent structure (Fig. 4.66). The load of the drying racks and their above roof structure is mainly supported by their own pillars. The beams between drying racks and the storage core are adjusted to prevent any leaning inward of the exterior structure, as there are not any keyed joints in between.

Enclosed-drying racks granaries are also found in other Dong villages, such as Zengchong and Xindi. They are all located in an area of 33 km in straight line from Dengcen. In appearance they are quite close to the granaries of Dengcen. However, they differ in construction in one significant way. The drying racks of granaries of Zengchong and Xindi rest on cantilevered ends of the lowest tie-beams (Fig. 4.67). In Dengcen, these drying racks are more independent structures. Both

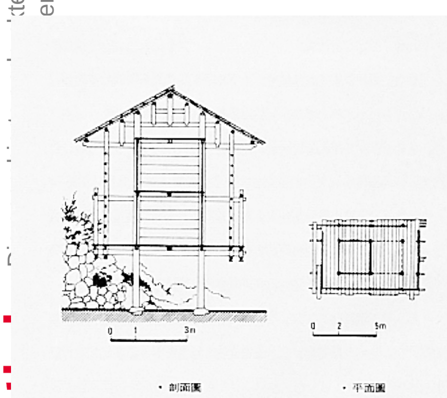


Fig.4. 67 The plan and section of a granary with drying racks in Zenchong, Congjiang, Guizhou(source: 陈从周 ,1997,p210).

methods of connection show advantages and disadvantages. For the Zengchong and Xindi, fewer pillars were needed in the construction. Thus the labour of building pillar bases was reduced. However, the ends of cantilever beams were prone to damage from rain and caused the structural failure of exterior drying racks. In Dengen, drying racks with their own load bearing members met the same problem. The exterior structures were prone to damage by rain in the same way. The inner granary construction is protected slightly better. However, as their drying racks are comparative independent structures, people can renovate them more easily without changing core structures of granaries.

4.3.3 Variant and change

4.3.3.1 Community granaries in People's Commune period (1958–1981)

During the People's Commune period[13], most of local villagers were asked to abandon their own private granaries and share community granaries. According to the scale of a village, the village could be divided into several production teams. In each production team, people worked together on fields of the production teams and shared all harvests from these fields (for further, see Section 2.10.2).

Most community granaries were different from traditional private granaries in the Dong areas. According to the interviews with locals,

13. The duration of People's Commune" varied in different regions. Here I follow the record in *Lipin Xianzhi*. (《黎平县志》编纂委员会, 1989, pp. 200-202).

Fig.4. 68 A former community granary in Qingzai, Liping,Guizhou.

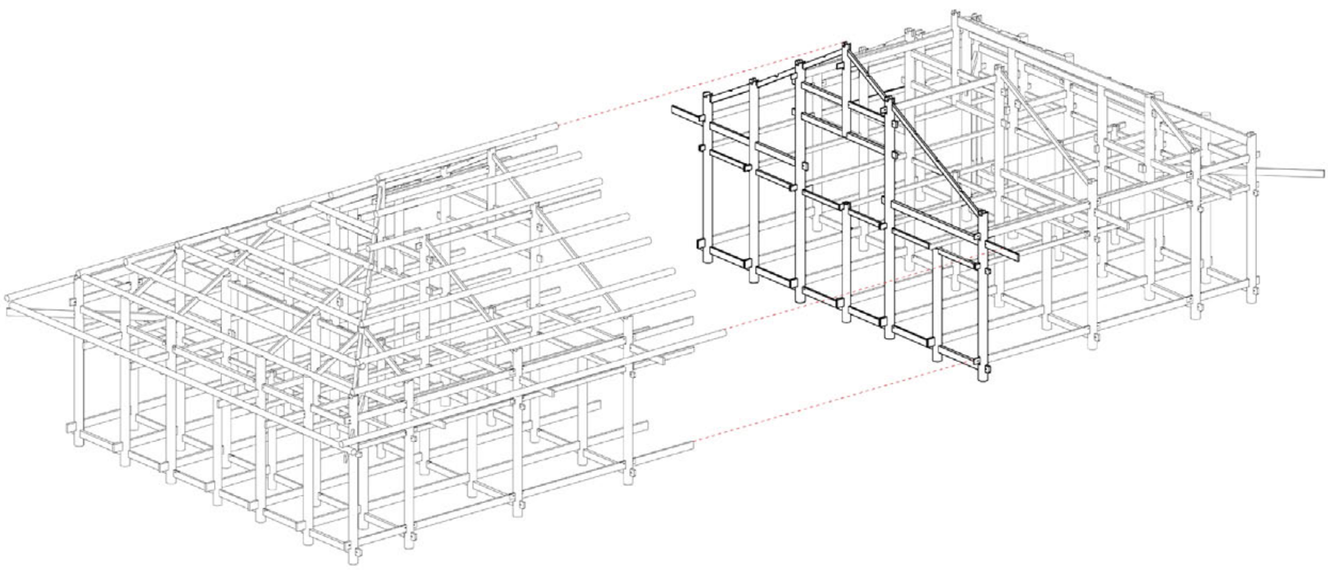


Fig 4. 69 The framework of the granary

there used to be several community granaries built in Dengcen in the People's Commune period. However, they were demolished soon after that period. Aiming to detect the building technique of these community granaries in the People's Commune period, a community granary from a neighbouring village Qingzai was selected for further study.

Built in 1977, this selected community granary was one of four public granaries in this village (Fig. 4.68). Locals said that this granary was initially designed with a storage capacity of hundreds of tons. After the end of the People's Commune period, local farmers divided it into dozens of equal storage rooms and turned them into private granaries. The division of storage components followed the column pattern. Each storage room could store nearly 6,000 kilograms of rice according to locals. The granary is located at the junction of rice paddies and the residential area. There is one public drying space in front of the granary, which is necessary for normal rice harvest. According to the policy during People's Commune period, sticky rice planting was restricted (罗康智, 2012, p. 114). Instead, all villagers were to plant normal rice. Thus, community drying spaces became necessary.

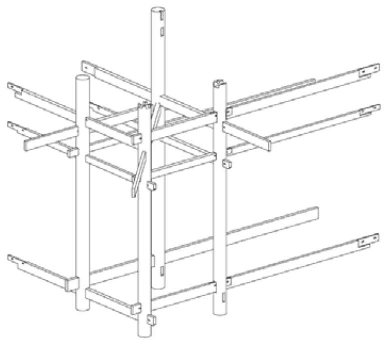
At 19.8 meters long and 10.1 meters wide, the area of this granary is almost 20 times larger than that of the ordinary granaries. This was a big challenge for the local carpenter at that period. Moreover, the lack of timber material[14] probably increased the difficulty of any construction. Local carpenters had to overcome two major problems if they intended to erect such a huge wooden granary: (1) how to cover such a big space with one single roof structure; and (2) because when the amount of stored grain increased, the load and the lateral thrust acting on the structure also grew, how to enhance stability of

14 Due to the cultural revolution and peoples' commune, traditional afforestation almost entirely vanished in between 1960-1980. And large-scale deforestation events happened several times in this area during this period (《黎平县志》编纂委员会, 1989, p. 310). All of this led to a severe lack of timber material in late 1970.

the whole structure.

Local carpenters decided to erect a huge hipped roof to cover the rectangular plan. A pitched roof structure is widely applied in traditional granaries of this region. In respect to building technology, a hip roof structure is more complex than a pitched roof structure. Thus, the hipped roof was generally used as a symbol of high-level architecture, such as in temples. In the hip roof structure of this community granary, inclined beams connected to pillars' top ends were used for carrying purlins (Fig. 4.69). Such a structural arrangement differs from the traditional *Chuandou* structure system. It is also hard to recognize as a truss structure. It can be seen as a structural solution under economic pressure, since the application of inclined members can save material and labour. This roof structure is even not symmetrical: there are more pillars carrying inclined members in one side than on another side. It seems that the whole roof structure was erected in a quite rough and immature way. This evidence supports the idea that this granary was built under conditions of wood shortage in the 1970s. Facing the situation of the shortage of large logs, local carpenters had to find a way to work with these thin and short logs, thus creating this unique roof structure to cover the huge plan underneath. Nevertheless, some deformation evidence in the current roof structure shows that such kind of roof structure is not so stable (Fig. 4.70).

The storage space is defined by the framework and infilled walls. Apart from two minor side bays, the average column spacing along the longitudinal direction is around 3.2 meters. It is similar to traditional granaries in this region. However, the average column spacing along the transverse direction of this public granary is around 1.7 meters, which is almost half of that in typical traditional granaries. Meanwhile, the dimensions of structural members of this granary are generally smaller than in most local ordinary granaries



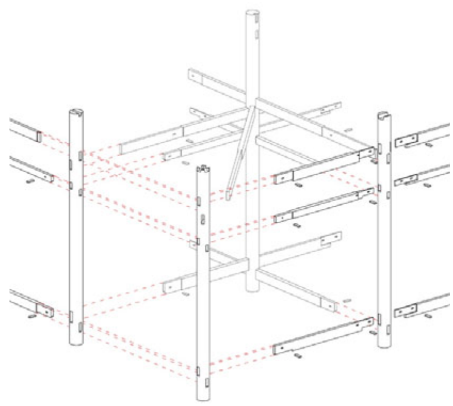


Fig.4. 71 Construction detail of a corner of the granary

Fig.4. 70 A post was added to support a damaged inclined beam of the roof in the community granary

built before the 1960s. This suggests that the local carpenters wanted to enhance the stability of the whole structure by reducing the spans of the tie-beam between pillars. They were searching for a solution to compensate for missing appropriate building material and being confronted with significantly heavier grain load (Fig. 4.71).

4.2.3.2 Granaries built after 1980

The People's Commune policy was generally stopped in the early 1980s (《黎平县志》编纂委员会, 1989, p. 310). Villagers gained their own lands and started using private granaries again. Some villagers repaired and used old granaries built in the last generation, and some villagers brought and shared former community granaries. Some people decided to build new granaries.

New granaries share a similar appearance with old granaries in most cases. However, analysed in depth, they provide two new characteristics: (1) the dimensions of structural members of new granaries are mostly smaller than old granaries, and (2) the beam sections of new granaries have changed. Both of are related to the lack of large-diameter timbers.

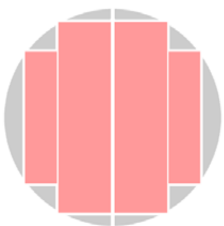


Fig.4. 72 Carpenter usually cut the log by the mechanical saw in this way and take the red areas for making beams and planks.

After 1980, due to the change of the ownership of woodlands, fir trees were generally felled when they were 18–20 years old (LUO, 2008, p. 103). This harvest cycle created much smaller dimensions for logs than was the case before. Consequently, the dimensions of structural members became less than before. The lack of large-diameter logs required carpenters to make full use of thin timbers. The former cutting measure of beams causes the height of a beam to become much smaller than its former diameter. Thus, carpenters changed the design to become simpler and more economical : they keep the heart part of the log and cut the whole log into beams and planks (Fig. 4.72). This method of cutting creates beams with rectangular sections, which led to the disappearance of beams with semi-elliptical sections in newly built granaries.

Meanwhile, carpenters insisted to arranging pillars in the former large column spacing with thin beams when building new granaries. The application of thinner structural members in granaries raises the risk of structural failure when the column spacing stays the same as before. Aiming to prevent this, supporting posts are added in some new granaries (Fig. 4.73).

Fig.4. 73 A newly built granary in Dengcen, Liping, Guizhou.

4.4 Dong village: Gaoding

Gaoding, home to 646 families (2,483 people), is a typical large Dong village located in a mountainous area, situated in the eastern edge of Yungui Plateau (陈容娟 , 2015, p. 10). Compared to Dencgen, the surrounding terrain of Gaoding is steeper. Even using terrace construction technology, arable fields for planting rice are still few. Now, the per capita arable land area of Gaoding is around 0.3 *Mu*, nearly half of Dengcen (韦玉姣 , 2010, p. 86) (Fig. 4.74).

4.4.1 Village, dwelling, and granary

The whole village is located in a deep valley of a mountainous area. A stream used to flow through the valley, providing drinking water and irrigation water for the village. However, this stream was covered and turned into an underground channel during the past 20 years. Instead of the stream, a new concrete road passes through the centre of the village.

Villagers built their dwellings on slopes on both sides of the valley. The original slope angles were between 10–26°, some areas even reaching 33–40° (韦 玉 姣 , 2010, p. 86) (Fig. 4.75). Aiming at building dwellings on such steep slopes, the Dong people started to turn original slope surfaces into a series of terraces when they decided to settle down the area. To build these terraces, people cut and filled original slopes, rammed the ground surfaces of these terraces, and built retaining walls for terraces with pebbles. Such a project requires a large amount of labour and investment of time. Thus villagers always wanted to make full use of the limited area of these terraces. They arranged their dwellings in an extremely dense manner. Intervals between the buildings were generally so small that gable eaves of nearby dwellings can even touch each other. Only narrow passages remain in front and behind these buildings. Such intensively dense building design causes fire-prevention problems, but it also provides a benefit. The continuous eaves of these building

Fig.4. 75 Sections of the residential areas of Gaoding village. (source: 韦玉姣 , 2010, p. 87)

Fig.4. 74 Gaoding, Sanjiang, Liuzhou, Guangxi.

Fig.4. 76 Residential areas of the five different clan groups of Gaoding are divided with clear boundaries in the past. (source: 韦玉姣 , 2010, p. 86)

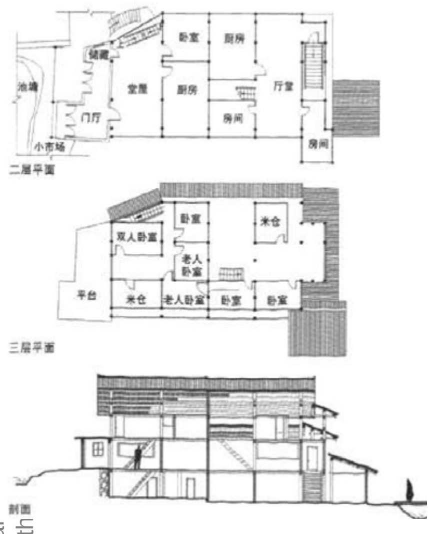


Fig.4. 77 Plans and a section of a dwelling shared by two families. (source: 韦玉姣 , 2010, p. 88)

15 An extended family is a family that extends beyond the nuclear family, consisting of parents like father, mother, and their children, aunts, uncles, grandparents and cousins, all living in the same household.

groups can largely protect the wooden walls of both the gable sides and rear sides of buildings.

In such highly compacted villages, fire-prevention is one of the primary public affairs. A series of fire-prevention regulations have been strictly enforced in this village for hundreds of years (韦玉姣 , 2010, p. 87). In addition, the whole large village used to be divided into five separate residential groups, so the whole village is assembled into five clans. Each clan was intended to gather and remain separate from the others; thus, in the past they kept a certain distance from other clans. This idea promoted the generation of natural boundaries between these residential groups. These boundaries usually consisted of steep slopes, ponds, and stream areas (韦玉姣 , 2010, p. 86) (Fig. 4.76). These undeveloped areas could also act as fire barriers, thought to prevent the fire from spreading over all the village. These measures seem to have been effective, as there has been no large scale fire disaster occurring in this village for nearly a hundred years. This situation is quite rare among Dong villages. In local peoples' concepts, this could be seen as a sign that the village continues to run in good order. However, due to the increasing population of the village in recent decades, the lack of construction land drove locals to fill ponds, cover streams, and built new dwellings in these boundary areas in recent decades. In the newly built dwellings locals mostly enclosed their kitchens with brick walls. This helps to reduce the probability of fire when former fire barriers disappeared.

Many families of Gaoding chose to live together in an extended-family[15] mode in the past. It was quite common that two or three minor nuclear families with blood relationship live under the same single roof in Gaoding (韦 玉 姣 , 2010, p. 88).In such type of multi-dwellings, each minor family respectively had their own fireplace room, bedrooms, and storerooms. Apart from these, the majority of them even have separate entrances and staircases (Fig. 4.77). This may also be related to the shortage of construction land of this village.

There are two types of rice storage methods in this village: storing rice in attics of dwellings and storing rice in independent granaries. The former one is usually used in the situation that the amount of stored grain is not so much. And it can also be related to that the wide application of brick walls used in kitchens largely reduces fire risk of dwellings after the 1980s (韦 玉 姣 , 2010, p. 89). Consequently, I would like to bring interplay to another condition. Storing rice in attics seems to be an answer to lack of enough building site and a decrease of per capita arable land after the 1950s (韦玉姣 , 2010, p. 87).

Independent granaries still exist and some of them are still in use nowadays. The number of existing independent granaries is far less

Fig.4. 78 A former granary was transformed into a dwelling in nowadays.

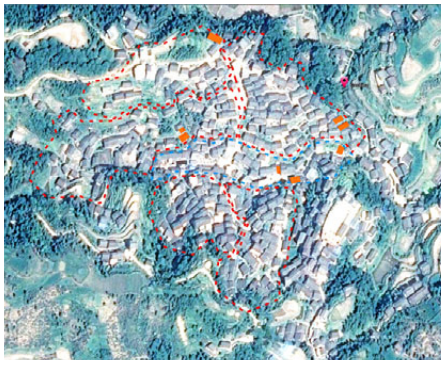


Fig.4. 79 A satellite map with the location of selected granaries, former clan boundaries, and the former stream area.

than the total number of households in Gaoding. It is supposed that some granaries had already been demolished in the past decades, and some of them had been changed into dwellings (Fig. 4.78). Nowadays, only a few villagers still own independent granaries, the majority of villagers choose to store their rice in attics.

One interesting fact is that the existence of these granaries is ignored by many Chinese scholars who had studied Gaoding. Most of them stated that the only rice storage method of this village is storing rice in dwellings (韦玉姣, 2010, p. 87；熊伟, 2013, p. 101). This strange assumption could drive from the fact that many local granaries are located in residential areas or next to dwellings or converted to dwellings. I attribute this special phenomenon to the change of the layout of the village in the last 60 years. Most of existing independent granaries were built before the 1950s. When we bring together locations of selected granaries, the former clan boundaries, and stream area on the same satellite map, we can easily conclude that initial locations of these granaries were formerly in boundary areas or along the stream (Fig. 4.79). This meets the traditional criteria for granary sites in Dong area: far away or at the edge of residential areas.

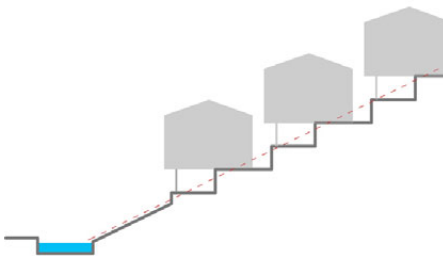


Fig.4.80-a A diagrammatic section of the terraced land for building dwellings.

Most of former boundary areas were steep slopes even steeper than ordinary residence areas. This is also the reason why locals left them as open space since it would cost a lot of labor to convert them into terraced land, on which dwellings can be built. However, foundations are still the must for building stable construction on slopes. Based on the investigation of several granaries built on slopes, for building the basements of these granaries, builders usually preserved the main part of outlines of the slopes and built several narrow pebble foundations on different height along the slope (Fig. 4.80). However, this kind of foundation also rises problems as time goes

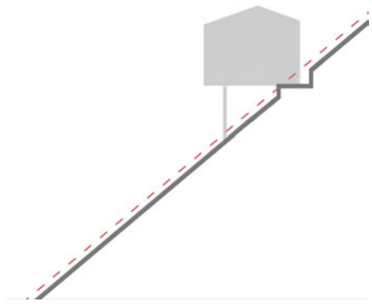


Fig.4. 80-b A diagrammatic section of the A diagrammatic section of the slope for building a granary.

Fig.4. 81 G4 granary was built above a pond next the stream in the past. (source: Klaus ZWERGER)

by. Firstly, many granaries built on the slopes would ask for longer supporting pillars to adjust to the topography. Secondly, narrow pebble foundations were easy to be damaged by rainwater over time. Hence locals invented methods to remedy this problem. They elevated the pillar bases by installing more stone beneath.

Concerning to granaries built along the former stream, I suspect that the majority of them might be initially have been built above ponds, as is shown in the old picture (Fig. 4.81). When we compare these granaries with others also built above ponds, like granaries in Dengcen, we can notice that raised floors heights of Gaoding's granaries are generally higher than compared to them.

4.4.2 Granary and its construction

Nearly all of existing granaries of Gaoding are wooden buildings with raised floors, pitched tiled roofs, and equipped with drying racks. One most obvious characteristic of these granaries is the number of their drying racks attached to granaries. Most of granaries have more than one row of drying racks (hereinafter referred to as: multi-row granary). Granaries with a similar appearance are also distributed among other nearby mountainous areas in Sanjiang area, Guangxi. This is quite different from granaries of Dengcen, which are mostly without drying racks or only one row of drying racks (hereinafter referred to as single-row granary). These granaries with only one row are mostly found in valley areas with more gentle terrains.

Many villagers believe these granaries are more than one hundred years old. The planting area of sticky rice in this region decreased after the 1950s, therefore I speculate that granaries with so many drying racks were mostly built before the 1950s (广西三江侗族自治县县志编纂委员会, 1992, p. 91). Another already mentioned fact confirms the villager's conviction. As there was no large fire disaster occurring in the last one hundred years old, it is possible that these granaries were built before the 1950s.

The existing granaries of Gaoding present a great diversity in their forms and scales. It is even hard to find two granaries with a similar appearance in this village. In horizontal direction the number of bays of these granaries can vary from two to seven, while in vertical direction granaries' floors vary from one to four. Two to three-story large granaries are quite common here. The diversity of these granaries might partly be related to their varying ownership modes. Similar to their dwellings inhabited by several families, it is quite common that several small families with blood relationship chose to build their storerooms together into one building. The scale of a granary is likely to have a relationship with the number of families which intended to use the granary together and they were involved in the construction. And their main consideration is also similar:

making full use of the limited construction land in such a densely packed village.

Another significant feature of local granaries is that nearly all of them own other functional spaces beyond grain storage and drying. Many granaries own agricultural tool-rooms, working places, sometimes fireplaces for short rest, or even temporary living rooms. Besides these, many villagers store their construction timbers under the main floors of their granaries.

4.4.2.1 Types of granaries and the relationship to terrain

Granaries of Gaoding were built with '*Chuandou*' system, which is similar to dwellings and some other constructions in Dong villages. In a granary, *San* is an important element being related to the structure and layout of the building. According to pattern types of *San*, granaries of Gaoding can be classified into two main categories (Fig. 4.82):

i. Granaries with asymmetrical *San*. Their *San* are characterized by a distinct separation of storage rooms and drying space. This separation is defined by the central row of pillars. The central pillars in the transverse direction roughly divides into two halves: the mountain side housing the storage rooms, the valley side reserved for the drying racks (see G1).

ii. Granary with symmetrical *San*. The storage rooms of these

Fig.4. 82 Sections of the selected granaries in Gaoding.

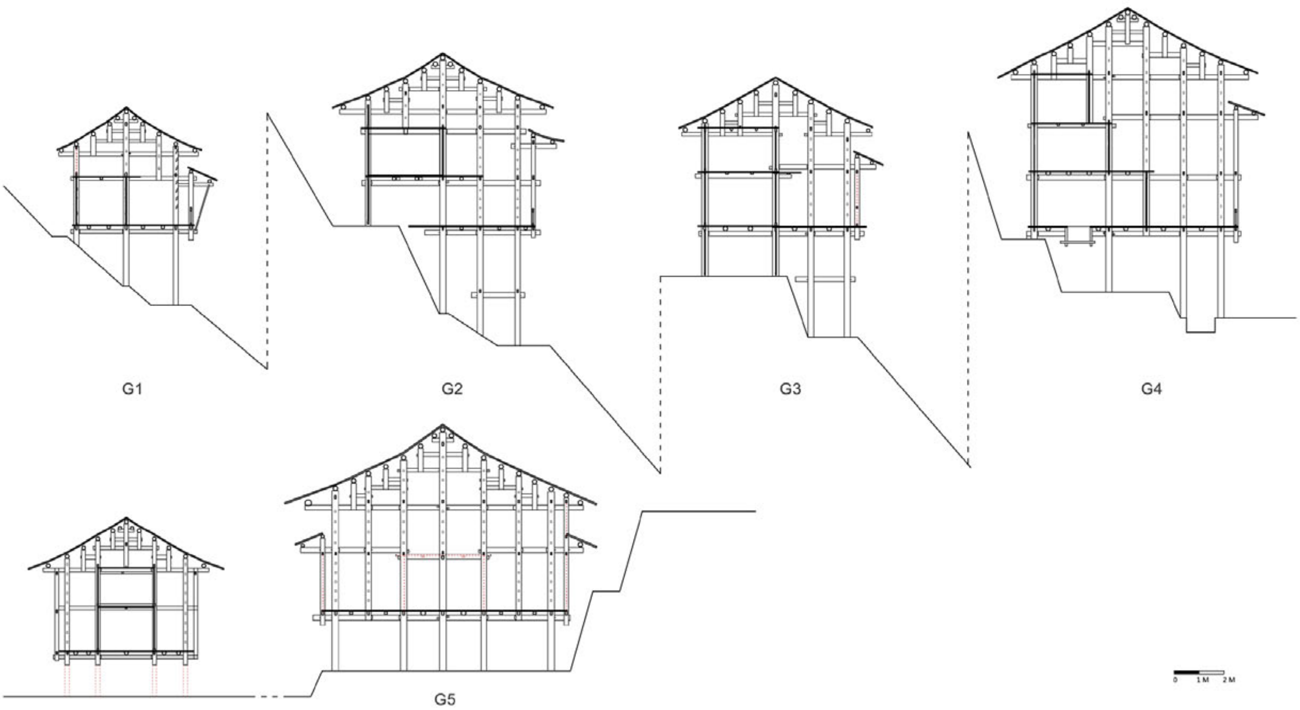


Fig.4. 83 A damaged framework of a granary.

granaries are located in the centre of the building, while the drying spaces are located on both front and rear sides. There are cases in which drying ladders are found in the storage rooms . One of those examples is G5. Granaries of this type are mostly located on plane ground.

Considering the distribution of these two types of granaries in Gaoding, we recognize the placement of asymmetrical *San* or symmetrical *San* in a granary related directly to topography factors of its building site. Apart from the terrain, I believe that the actual determining factor is wind. In respect to granaries with drying racks, how to use wind in most effective way became a key factor in arranging the layout of a granary. When people need to build a granary on a slope, the builders tried to install the drying space side of this building facing the valley side, aiming to gain stronger winds on that side of the building . Having in mind Gaoding's terrain, this design choice largely leads to the development of granaries with asymmetrical sections. On the other hand, a granary is built upon a plane area, there is no significant difference concerning the amount of wind between rear side and front side of the building. Thus, most layouts of those granaries are symmetrical.

Aiming to get a comprehensive understanding of the traditional granaries in Gaoding, I selected five granaries with different scales and forms to conduct detailed measurement and further analysis here. Due to the unavoidable change of ownership and the aging of the structure, most of these granaries were damaged to different degrees. Based on a series of studies on the missing and damaged parts of the remaining structures, this investigation tries to reconstruct their original forms (Fig. 4.83).

4.4.2.2 Spatial planning

The spatial planning of granaries varies generally according to the change of its scale and the surrounding terrains. Apart from storage area and drying area, owners usually consider combining other functional space into their granaries, such as fireplaces, tool rooms, and so on.

Local carpenters usually faced following problems when designing a granary:

i. how to do deal with the site work and, when the building site has to be on a slope, how to deal with the base of the building?

ii. how to use wind and solar radiation in most effective way?

iii. how to protect wooden surfaces of the granary?

The following study on the five selected granaries describes the answers to these problems.

4.4.2.2.1 G1

This granary can be recognized as one of the smallest granaries in Gaoding. It has the basic functional elements of local granaries (i.e., drying racks, storerooms, and passages) in the most compact way. It belongs to one family. The owner claimed that the storage capacity of this granary could reach 4,000 kg (Fig. 4.84; 85).

This granary stands alone atop a steep slope, far away from its owner's dwelling. Builders did rough grading on the slope and built three rows of narrow terraces in different levels as foundations. The main floor is just raised a short distance from the topmost foundation. The distance between the front part of the main floor and the lowest foundation is already more than 2.5 meters, due to the steep slope. The entrance of this granary is designed to be in the front part of a gable wall. Thus in order to enter the granary one needs to lay some long wooden planks (they are usually stored in a nearby secret place) on short overhanging beams along one gable side of the granary(Fig. 4.86). Only walking over this narrow and rickety bridge one can reach the door of the granary, which is close to the frontage. This can be considered as a simple thief- prevention measure. Notches along the beams of the rear wall show that the carpenter initially designed a wooden fence between the roof and the ceiling in this granary which also aims at preventing strangers from entering the granary.

The granary is assembled by two bays in longitudinal direction: a

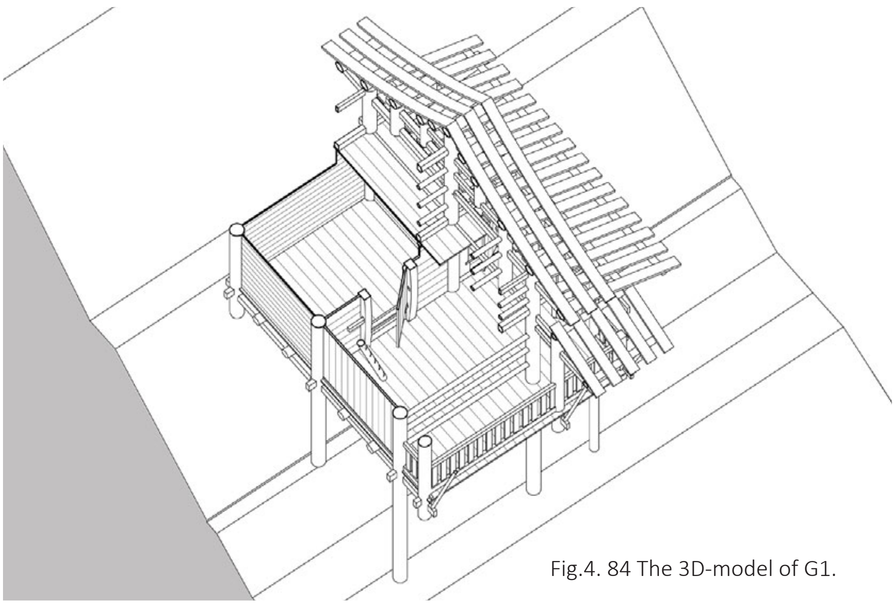


Fig.4. 84 The 3D-model of G1.

Fig.4. 85 The granary G1.

Fig.4. 86 A path leading to the entrance of the granary.

Fig.4. 87 Holes cut in the central pillar of the granary

Fig.4. 88 The extending ceiling planks.

Fig.4 89 A wooden boards with notches in the granary

major bay covered by the main pitched roof and a side bay covered by a lean-to roof. In the transverse direction, the granary can be divided into two nearly equal functional areas: the rear part is storage space, while the front part is rice drying space. There are two storerooms occupying the rear part of the granary. The larger one under the main roof served for storing sticky rice, while another smaller one is for storing tools. In the front half part, two rows of horizontal wood poles hold by pillars create drying racks for hanging sticky rice for around one month after the harvest.

In this granary, the main roof structure was elevated around 1 meter off the ceiling of storerooms. This provides a larger open attic space under the roof. As both gable sides are not enclosed, air ventilation in this area is extremely good. Holes at regular intervals in the central pillars imply that there used to be some drying racks (Fig. 4.87). This implies that carpenters intentionally design this space to enlarge the drying space in this small granary. A similar design was also used in G2. But such design had not yet been found to be used in large-scale granaries with two to three story storerooms.

A ladder is a must to enter the attic space,. Aiming at using the limited interior space in a more flexible way, a piece of log with regular notches is used as a ladder.

Concerning the attic space, one easily ignored detail is the cantilevered ceiling of storerooms (Fig. 4.88). In this granary one end of the ceiling of rice storeroom extends around 0.5 meters from the indoor vertical wall of the storeroom. This is an unusual detail since local carpenters were quite aware of the necessary amount of timber material. They won't waste any timber in any useless detail in the construction process. In respect to the original function of this attic space, I believe that this 0.5 meters wide extended part was initially designed as a passage to allow people to stay on this place for hanging rice without having to cross the drying racks in the middle. This also reveals how carpenters search ways balancing between compact spatial design and usage convenience.

In the front of drying space, there are a pair of wooden boards separately tied on opposite pillars. They are with inclined regular notches, which are used for holding drying racks (Fig. 4.89). Generally, carpenters cut holes ain pillars for the same function in granaries of Gadoing. However, in this small granary, carpenters did it in a different way in its front drying space. This can be related to the scale of the granary. Cutting holes into pillars can weaken the strength of the structure. This effect may be more pronounced in small granaries. In addition, In terms of construction complexity cutting notches on wooden planks is easier than cutting holes into pillars.

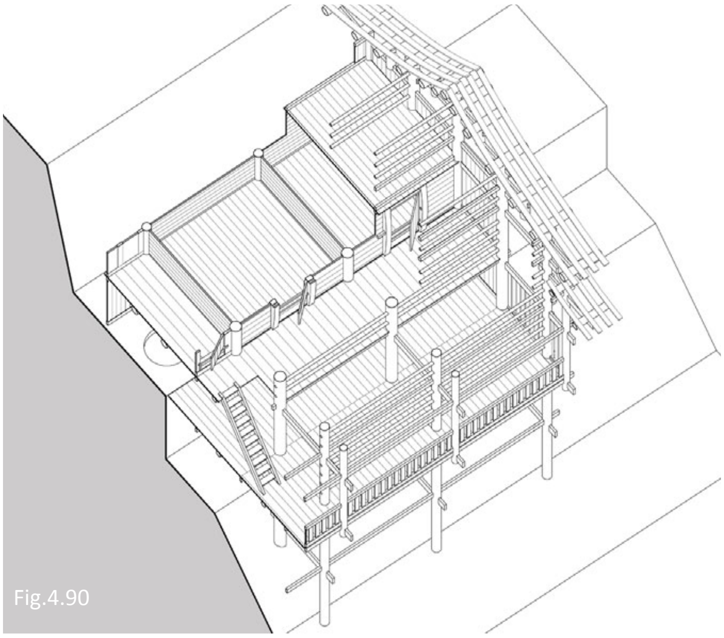


Fig.4.90

Fig.4.91

Fig.4 90 The 3D-model of G2

Fig.4 91 The granary G2

4.4.2.2.2 G2

The scale of G2 is much larger than G1. It is a two-storied granary with two grain storerooms and one tool-room (Fig. 4.90; 91). It belongs to two families now. The location of this granary is on the same slope as G1, but in a lower position. Next to this granary is a former granary, which had been changed into a residence now. Two adjacent gable eaves of these two buildings are so close to each other that one of the gables of G2 is perfectly protected against from the threat of rain. On the other gable side, carpenters built an extended side bay structure forming a staircase space. This extended structure provides a pent roof for protecting the gable side.

Although being located on the same steep slope, G2 was built in another way to adapt to the inclined site. Builders also carried out cut and fill work on the natural ground. Then they built three steps of narrow terraces at different at staggered height in the slope, according to the designed plan of the granary. The topmost base is the widest among these three. Builders prepared this plane as a part of the ground floor for the entrance floor and built a wooden platform in its front at the same level. These two parts together make up the whole entrance floor. Adding this wooden platform enlarges the indoor space and offers more indoor working space (Fig. 4.92). Moreover, the indoor lengths of pillars become longer, so carpenters can add more drying racks under the roof.

The interior layout of G2 has a pattern similar to that of G1: the front drying racks area, the rear storage area, and an additional attic drying space. The storage area, including two rice storerooms and a tool room, is on the rear part of the second floor. The front drying space is two and one-half floors of open space. Due to the large interior space, one wide wooden ladder was installed for carrying

Fig.4 92 The ground floor of G2

rice to the second floor.

What is left of an open fireplace was found in the ground of the entrance floor. The fireplace was initially dug directly into the rammed ground. Traces of smoke on the wooden ceiling under storerooms reveal that people had fires in this place. Such a fireplace is definitely quite dangerous for a granary. I think this fireplace might be occasionally used as a heating source only when owners need to have a short rest in the busy harvest time.

4.4.2.2.3 G3

This three-storey building with six bays is located on the eastern border of a residential area (Fig. 4.93; 94). Part of it is now turned into dwellings. Differing from the former two granaries, this long granary is located on two steps of wide terraces on a less steep slope. These wide terraces might be part of the continuous terraces originally made for the residential area. Two smaller granaries stand near behind it. Their eaves thus protect the rear side of G3 from rain (Fig. 4.95).

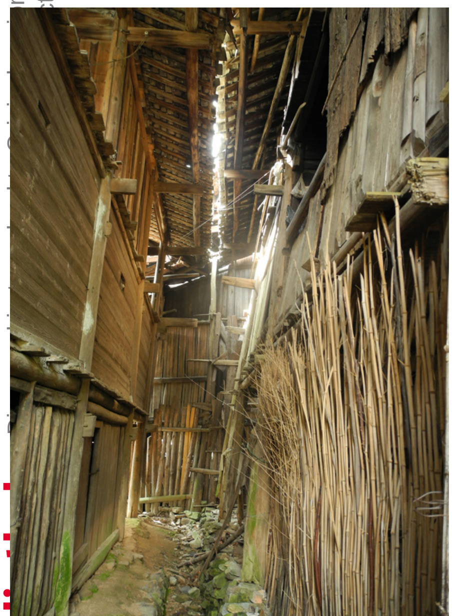


Fig.4 95 The narrow alley at the rear side of the G3

The ground floor of this granary is a half-public open space on a rammed-earth ground. Some parts of it were initially enclosed to serve as tool rooms and entrances with staircases. Now, some of the tool rooms are changed into residential rooms, with window openings.

The first and second-floor space is an indoor space enclosed by wooden fences and walls. This space consists of a series of storerooms in its rear and open drying space in the front.

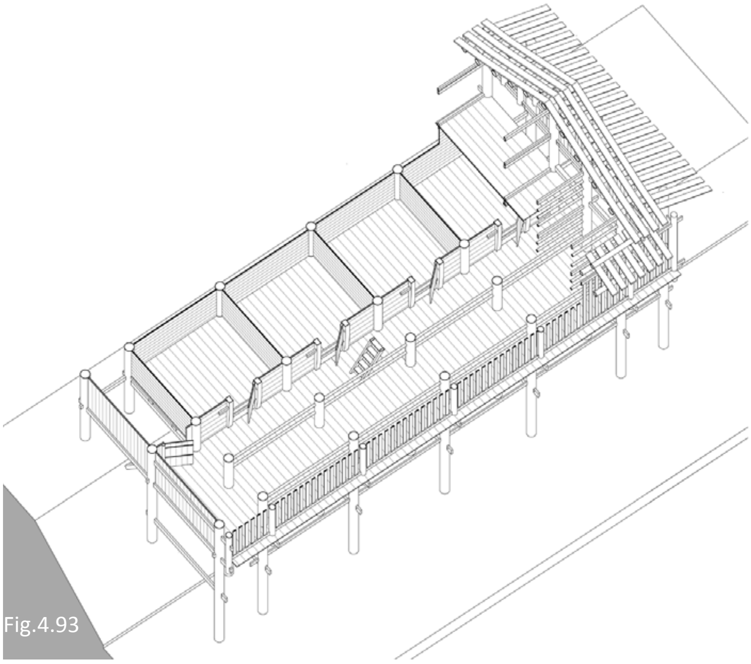


Fig.4 93 The 3D-model of G3

Fig.4 94 The granary G3

Detailed study shows that carpenters intended to build two floors' of storerooms in this granary. However, the third floor is still unfinished (Fig. 4.96). At the moment there is only one storeroom completed in this floor, while the rest part of the frame is left without infilled planks. This open space is supposed to become future storerooms. Such kind of partly unfinished buildings is not rare to be seen in Dong villages. This can be related to a building custom of Dong areas. In Dong villages, it is common that families with blood relations build a large house in order to share this building. Dong buildings' construction process stipulates that the main frame is done firstly under the help from experienced carpenters. Then each family continues to install floors, ceilings, and walls in their inhabited part during the following years. Due to different reasons, the progress of these finishing steps differs among different families sometimes. What we then see are unfinished buildings. However, the deep reason behind such a practice seems to be related to the restricted space in Dong villages. I tend to interpret this habitual appearance as a kind of perceptive preparation of living space. People occupy more space than actually needed in order to erect a large home for an extended family that might be in the future.

Based on the study of the damaged members of this granary, we recognize that the frontage and gable sides of this granary were initially enclosed by wooden fences in the past. Most of these wooden fences are missing nowadays. But small notches at a regular interval along the outside sills are unmistakable indicators. This might be due to the location of the granary next to a group of residential houses. Consideration how to prevent thieves' intrusion have led to protection measures of the granary.

Fig.4 96 Some areas on the second floor are still without enclosed walls.

4.4.2.2.4 G4

This four-story granary is one of the largest granaries preserved in this region. This building consists of four bays and a symmetrical layout along the central axis in the longitudinal direction. It consists of four grain storerooms and two tool rooms. We can infer from the separate two entrances on different gable sides that this granary might initially have belonged to two families (Fig. 4.97; 98).

This granary is located at the foot of a slope, next to the former stream region. According to a photo from 2002 (Fig. 4.81), the front part of the building was built above a pond. This placement is a common way to make full use of the limited construction land and also acts as an effective fire prevention measure in Dong villages.

The second floor of the granary is elevated 3 meters from the current ground floor. Above this main floor is a three-storey high drying space with four rows of drying racks in the front part (Fig. 4.99). In its rear part storerooms staggered in three storeys above each other. The depth of these rooms gradually decreases from the second floor to the fourth floor, aiming to create passages without adding additional structure and to strive for more drying space on the top of the granary. Similar to other granaries, this one boasts tool rooms on two sides.

Aside from its scale, this granary is outstanding for a unique feature: It includes two living rooms on its second floor, among all storage rooms. These living rooms are equipped with fireplaces. Building fireplaces in a large wooden granary seems unwise, and locals explain that the installation of a fireplace in a granary followed the idea to have a retreat after a dwelling has burnt down in case of fire or due to other serious damage. A homeless family could stay in this kind of room until a new dwelling could be constructed.

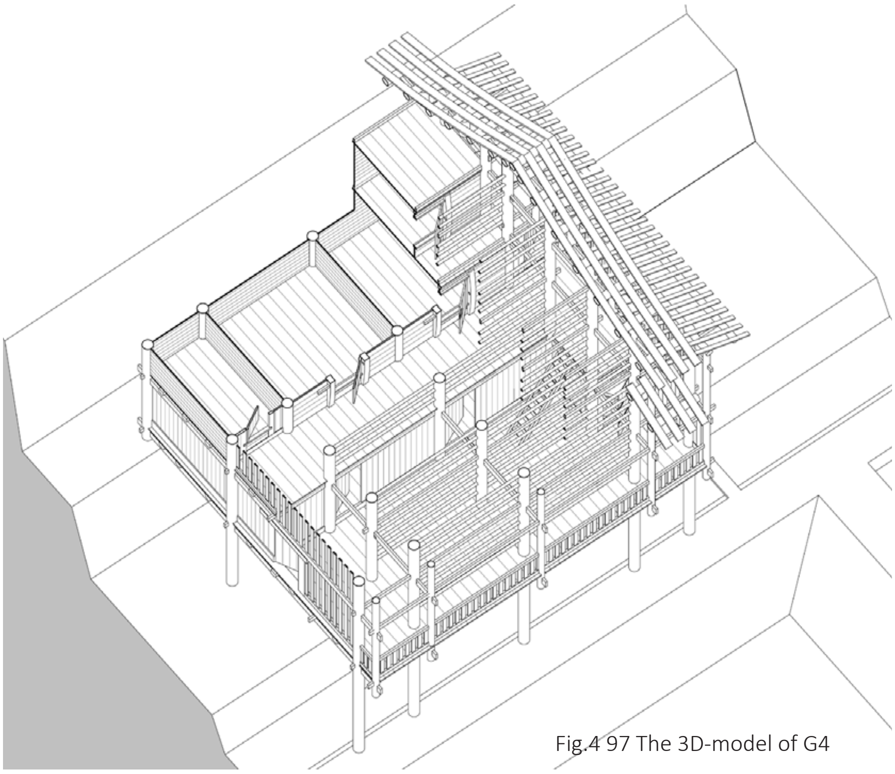


Fig.4 97 The 3D-model of G4

Fig.4 98 The granary G4

Fig.4 99 The interior of G4. (source: Klaus ZWERGER)

Nevertheless, it should be a temporary living space, otherwise this large granary would be likely to burn, eventually.

4.4.2.2.5 G5

Located in a former stream region, G5 now is a damaged wooden frame with a tiled roof (Fig. 4.100). According to the study of its damaged and missing elements, this structure used to be half of a large two-story granary with a symmetrical plan. The other half of the original granary was demolished and replaced by a new residential building. Due to the lack of construction land and the decrease of rice harvests, many old granaries have been similarly demolished in Gaoding.

A reconstruction drawing shows the original building (Fig. 4.101). It should be a large granary with four bays. The depth of the original structure reaches 9.8 meters. It is much larger than granaries built on the slopes.

The ground floor is half of a public open space nowadays used for storing construction timbers. According to locals, this granary was originally built above a pond that was filled years before. An entrance and staircase are on the ground floor, which is carefully enclosed by wooden planks. Another entrance on the second floor connects the granary’s rear side with the slope.

The second floor was probably the main floor. Its initial plan layout

Fig.4.100

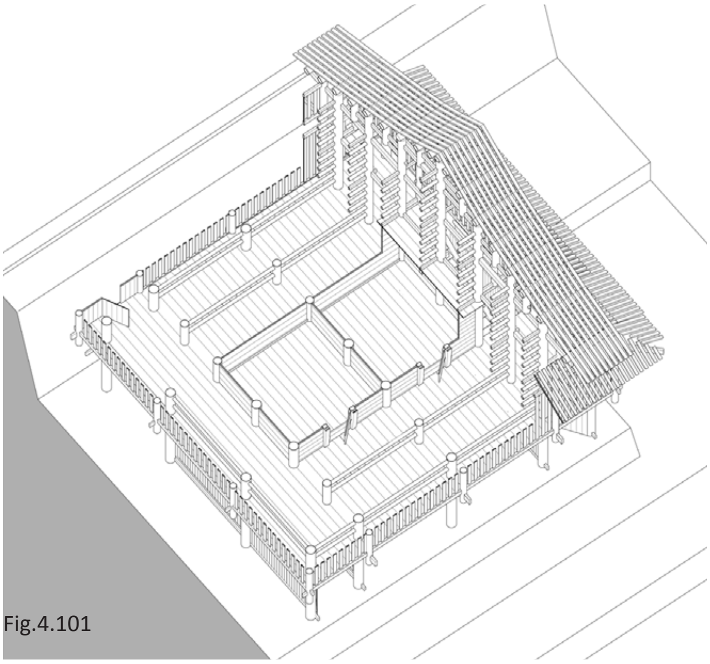


Fig.4.101

Fig.4.101

Fig.4.100 The damaged frame of G5.

Fig.4.101 The 3D reconstruction model of G5

Fig.4.102 Beams with through holes at regular interval imply the existence of wooden fences in the past.

was symmetrical in both transverse and longitudinal directions: two core storerooms were located in the middle, surrounded by drying racks on four sides. Regular holes in the pillars imply that there used to be an enlarged attic space above storerooms. The whole roof structure was elevated one story above the storerooms. This design enlarged the indoor drying space and increased the height of the building correspondingly.

Similar to other granaries of this village, carpenters attached a series of verandas with attached eaves surrounding the vertical surfaces of this granary aiming to protect the wooden structure from rain. However, due to the special height of the building, carpenters added one layer of eave between the main roof and the lower eave in both gables by installing a series of cantilevered brackets.

The whole building appears to have been enclosed by wooden fences initially (Fig. 4.102). There was even a group of additional fences between the main roof and minor roof beneath in the rear side, aiming to prevent a potential intruder from entering from the nearby slope.

4.4.2.3 Structure

Most granary structures in Gaoding present a strikingly complex spatial layout compared to ordinary granaries of other areas. Inevitably, carpenters had faced unusual challenges in these construction processes. In the construction of a granary located on a slope, one challenge is to ensure the stability of the structure bearing uneven loads and lateral thrust. If it is a large granary, an additional challenge is how to deal with the conflict between the limitation of timber and the determined building scale.

The following section offers structural analyses of these selected examples on different layers, aiming to provide further information about the structures of granaries on different scales.

4.4.2.3.1 Major framework and secondary structural members

Looking at load bearing conditions, the whole wooden skeleton of a granary can be firstly classified into two groups: the major framework and the attached members. The major framework is the part carrying nearly the entire load of stored grain and supporting the major roof. While attached members carry only their own building weights and dynamic loads (Fig. 4.103).

A major framework of one granary is usually assembled by several *Sans*（扇）and a series of longitudinal beams (Fig. 4.104). In a Chuandou structure, Sans are key structural members which

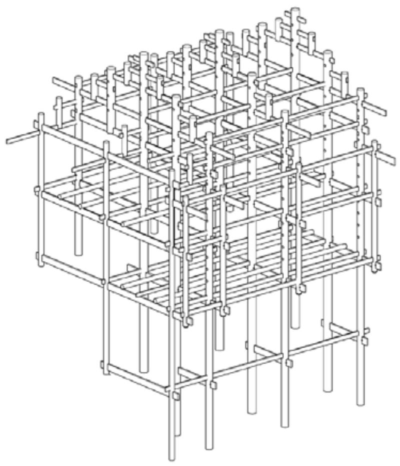


Fig.4.103-a The mainframe of G2

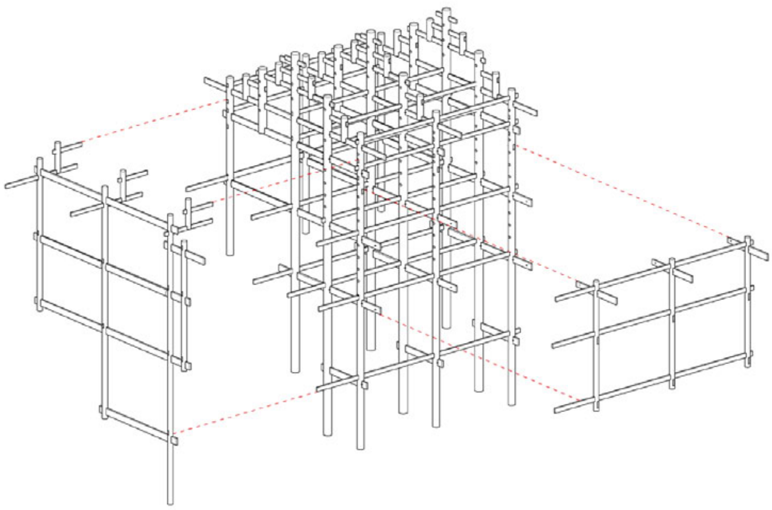


Fig.4.103-b Attached members of the mainframe

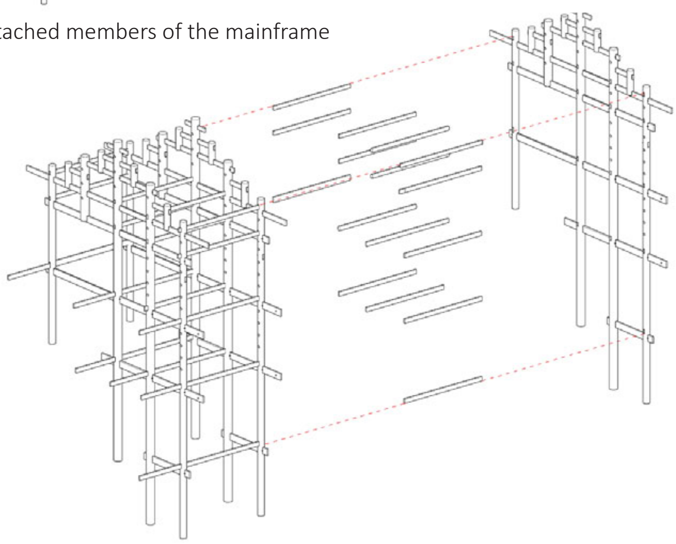


Fig.4. 104 A major framework of one granary is usually assembled by several Sans and a series of longitudinal beams

determine the inner spatial planning. Meanwhile, a stable Chuandou structure is based on a series of plane frames called *Sans* . Each *San* can be seen as a module, which shares the same pattern with the others. Moreover, in a typical Chuandou structure's building process, Sans should be assembled on the ground before the erection day in order to prepare for being pushed and pulled into upright position and put in its correct place. This preparation requires that the singular members are tightly connected to form the *San*. This measure simplifies the mounting process.

Longitudinal beams are used to tie *Sans* together and thus define their distances and form a stable framework. In most cases, longitudinal beams are not continuous beams when the number of *San* is more than two in one framework: they are spliced on pillar points. With such a design, such a framework can be extended to any determined length in the longitudinal direction by adding new *San* and new longitudinal beams.

Based on the measurements of the selected examples the conventional distances spanning distances between parallel major *San* among different cases are similar. They vary mostly between 2.8 meters and 3.0 meters. This shows that the conventional longitudinal span of a granary structure is shorter than that of normal dwellings, measuring 3.8 meter on average (蔡凌, 2007). This span could relate to different functional requirements of these two types of buildings.

The attached members are usually much simpler. Most of them are simple frames connected to the extended longitudinal beams or transverse tie-beams outside the major framework. They were mostly added to form side passages or overhanging verandas. Their joints to the major frame are usually simpler and weaker than joints applied in *Sans*. These attached members could this be more easily disassembled from the major frame. This ease would facilitate renovation work for the granary, since many attached members are exposed outside and would decay in local humid weather in a short time.

4.4.2.3.2 Longitudinal beam

Aside from fixing beams with pillars, most longitudinal beams also play other functions in granaries. According to their different locations, longitudinal beams might own different additional functions:

i. In storage areas, most longitudinal beams are also used to support ceilings and floors. They serve as a kind of load-bearing beams. In some cases, especially in top storerooms, ceilings are beneath longitudinal beams. In these cases, longitudinal beams are used to fix ceilings in their places.

ii. In drying spaces, longitudinal beams were used as drying racks during harvest time. This usage can be implied by intervals between these longitudinal beams and other pure drying racks, which are similar to conventional intervals among horizontal drying racks.

In some granaries, the topmost longitudinal beam acts only as a kind of pure tie-beam. Its function is to take the large pulling force along the longitudinal direction in the upper part of the structure, aiming to reinforce the structure. However, this beam is absent in some granaries, such as G2.

In large granaries such as G2 and G3, most of their longitudinal beams are spliced beams. Being assembled of several members with similar length, they are spliced where they meet in pillars. The number of members of one longitudinal beam are usually determined by the number of bays in one granary. The primary advantage of such a design is to facilitate the erection of the building. Another mentionable point is that the length of building can be out of the restriction of available timbers.

Detailed measurements show that carpenters developed different types of spliced joints for longitudinal beams in different positions and in different granaries (Fig. 4.105;4.106;4.107). A common feature of these joints is that wooden nails fixing these splicing joints are adapted on two sides of pillars. Thus, the elongated beam is restricted from sliding into the pillar’s hole. The pillars are fixed in their position. This structure reveals two main tasks of these jointing details: splicing two pieces of longitudinal beams and fixing longitudinal beams to pillars.

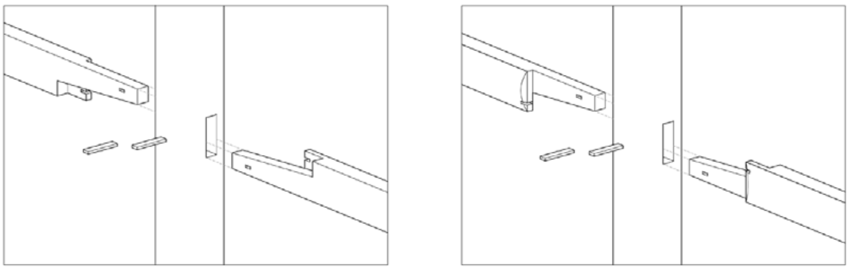


Fig.4 105 A spliced joint for connecting one beam with a rectangular section and another one with semicircle section in the longitudinal direction.

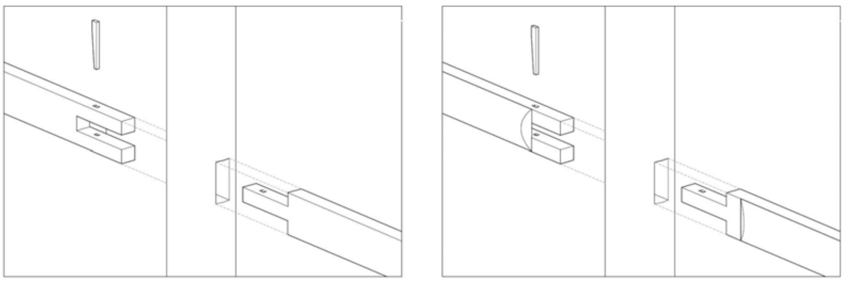


Fig.4 106 A spliced joint for connecting two beams with semicircle section in the longitudinal direction.

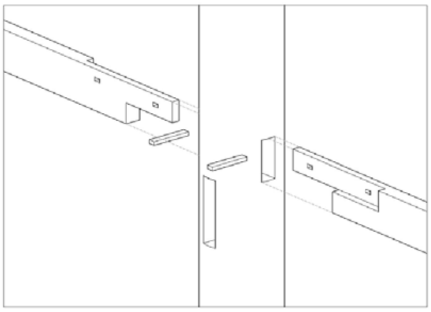


Fig.4 107 A spliced joint for connecting two beams with rectangular section.

4.4.2.3.3 *San*

Sans are transverse frames of the major framework in the structure of a granary. Carpenters designed different types of *San*, adapting to different demands for building scales and spatial layouts (Fig. 4.108).

A *San* is mainly a plane frame woven by several vertical pillars and horizontal tie-beams. The spacing between pillars usually has a conventional value in this certain area. The selected granaries show that, generally, two different types of column spacing exist in one *San*, according to two different functional requirements. In storage space, the pillar span is usually between 2 to 3 meters, while in a drying area, the pillar span is usually half of this length. Since the pillars of the drying area are usually also the posts of drying racks, carpenters were inclined to add more pillars at smaller intervals in the drying area of a granary. The main reason is the provision of increased drying capacity.

In a *San* of a granary there are usually two types of horizontal structural members: tie-beams and supporting beams. Generally, tie-beams connect all main pillars. They are connected with pillars by keyed joints. Supporting beams are usually short beams necessary for creating the roof structure. Their main function is to support intermediate short pillars of the roof carrying additional necessary purlins. These short supporting beams in most cases are connected with pillars by simple through tenons or stub tenons, which are weaker than keyed joints (Fig. 4.109); however, there are also exceptions. Some short beams of roof structures of granaries are keyed to pillars, as shown in G2 and G3.

Tie-beams' main task is to hold the pillars together and to prevent them from leaning in the transverse direction. Many of them are also used as load-bearing beams in granaries, supporting ceilings and floors. Thus the vertical intervals between tie-beams usually follow the determined heights of different stories in a granary. In some examples, such as G1, G2, and G5, carpenters sometimes

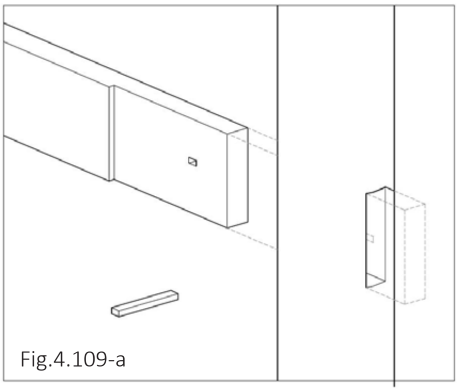


Fig.4.109-a

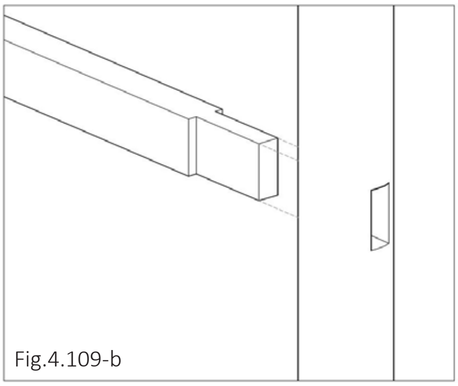


Fig.4.109-b

Fig.4.109-a A connection with keyed joint

Fig.4.109-b A connection without keyed joint

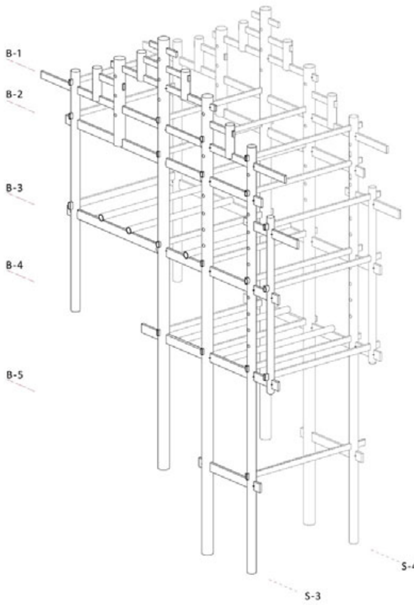


Fig.4.108-a *San* of G2

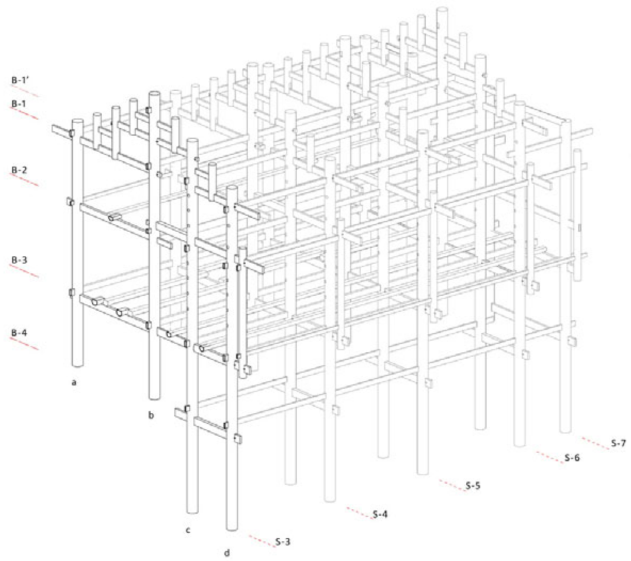


Fig.4.108-b *San* of G3

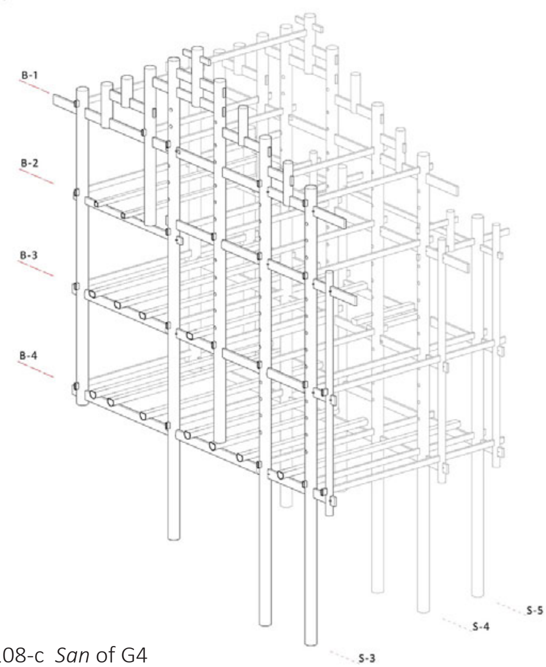


Fig.4.108-c *San* of G4

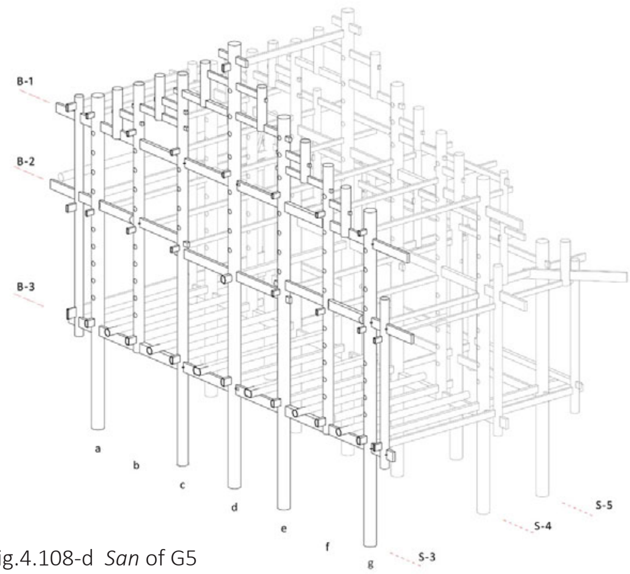


Fig.4.108-d *San* of G5

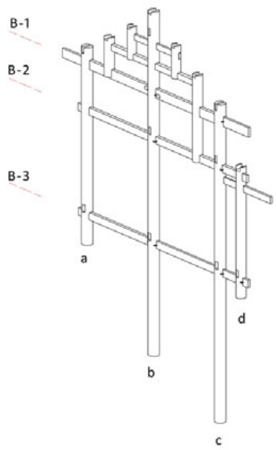


Fig.4.110-a *San* of G1

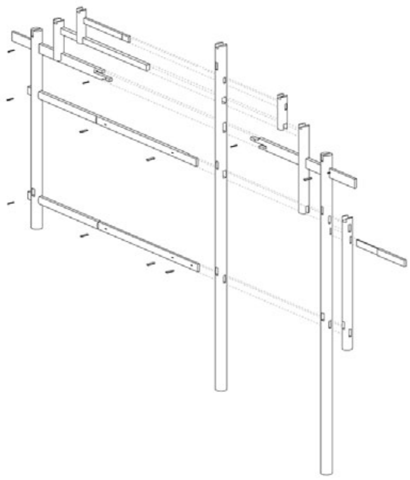


Fig.4.110-b A disassembled *San* of G1

added one more tie-beam between the top of storerooms and the roof structure in order to stabilize the enlarged attic space.

As mentioned before, *San* needs to resist two types of force: vertical loads from the roof and stored grain, and side thrust from stored grain. In granaries with asymmetric *San*, vertical loads are uneven in their front part and in their rear part. Local carpenters had to solve the problems to ensure the stability of such kind of structures.

I take one *San* of granary G1 as an example. Shown in image Fig. 4.110, three tie-beams are used for fixing pillars. Particularly, sections of the two lower tie-beams vary in shape. In between Pillar a and Pillar b sections of the two beams are round. Carpenters do this by partly preserving the original outline of logs. Meanwhile the portions outside Pillar a and Pillar b own rectangular sections, which are definitely smaller than round sections. Their ends protruding from Pillar c are still smaller. These features impart two main advantages:

i. They fix pillars and tie-beams in a strong way. The portion with round section can act as tenon shoulder in one side of the pillar, while key joints fix pillars on the opposite side. Thus, this joint can prevent pillars from leaning outwards or inwards.

ii. The heavy labour work of shaping logs into beams is reduced, since carpenters preserved part of the original shape of the log. Therefore, this type of special tie-beams was widely applied in the whole framework of granary structures among Dong villages, acting as one of the most efficient lateral connecting methods.

Apart from the load of the roof, the load of stored grain is usually considered to be the largest load in a granary. Measuring the structural members of selected granaries proves that the heights of beams beneath grain storage rooms are generally larger than those of other beams in the same granary. In most cases, they retain their original unworked shapes. Keeping the largest possible section of a beam, carpenters consider this as a single and effective reinforcement method for the structure.

4.4.2.3.4 Limitation of construction timbers

Due to the difficulty of transportation, timbers used in building construction are limited in a certain range in Dong villages. In the construction process of a granary, the finest and longest logs are usually used as pillars, then shorter logs are used to make beams and planks. Measurements of granaries of Gaoding show that most pillars are shorter than meters, while most beams are shorter than 6 meters. In the construction of a granary, carpenters would always meet the challenge to balance the requirement of large scale building and the limitation of building materials. Since the application of spliced beams in a longitudinal direction makes the elongating building along this longitudinal direction not a problem, the major problem becomes how to solve the materials' limitations in the vertical direction and in the transverse direction.

In the vertical direction, the height limitation of pillars is not a problem in small granaries such as G1. People can even lift the roof to enlarge the drying space, besides lifting storage rooms above the ground. However, in large granaries, carpenters needed to calculate more carefully. Taking G3 as an example, the longest pillars of this granary are around 9.4 meters long, shorter than the longest pillars of G2. However, G3 is a three-storeys granary, while G2 is a two-storied granary. Obviously, carpenters were asked to create more storage space; thus, they need to find a way to build a three-storeys granary under a very limited height. These 9 meters-long logs were used as pillars of the front part of the building to adapt to the steep slope. The length of central pillars standing on the topmost terraced ground is only 7.7 meters (Fig. 4.111). Since carpenters give priority to ensuring the indoor space of the ground floor and the second floor is within conventional heights, the distance between the second and third layers of the tie-beams in storage spaces has been reduced into 1.45 meters. If storerooms did not offer sufficient height, the same problem would occur with the space in front of the granary. This space is reserved as a corridor to enter and leave the storerooms and fill and clear the drying racks. The carpenter solved the problem by interrupting the upmost tie-beams. However, the tie-beams cut into two halves definitely weakened the stability of the whole San structure. Carpenters solved this deficit by inserting beam B-1' into the roof structure serving to anchor Pillars b and c by key joints and make them part of the roof structure. This approach could be seen as a remedial measure to ensure the stability of the whole frame.

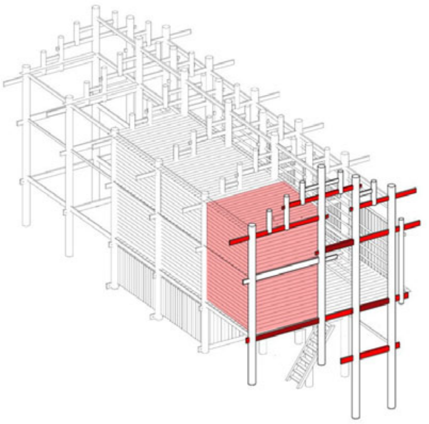


Fig.4.111 The length of central pillars standing on the topmost terraced ground is only 7.7 meters in the G3

16. Main pillars refer to pillars standing on the ground floor and therefore being important parts of the load bearing structure.

The detailed study of the structure of granary G4 provides further information on how local carpenters built a wooden structure higher than the available construction timbers. The height of G4 reaches 11.4 meters, while the longest pillars of this building are 10.8 meters. As shown in image 108-c, the important central pillar b was slightly shifted away from the geometric middle axis of *San*. Instead of it, a short post is put on a beam, which is carried by the central pillar and another pillar, to support the highest ridge purlin.

In the transverse direction of a granary, carpenters face a new problem. Aiming to reduce the use of long logs, carpenters mostly preferred to apply short logs to make tie-beams. In all investigated examples, only G1 uses two layers of unspliced beams as tie-beams in transverse direction. In granaries with larger depth along transverse direction, spliced beams are widely applied to tie in all main pillars (Fig. 4.112)[16].

Further analysis suggests that the application of spliced tie-beams is not related only to material limitations but also to the processing of wooden components. Investigation of the splicing joints of selected examples demonstrates that tie-beams of large granaries usually consist of two to three connected beams. The singular segments usually connect two to three main pillars in a San. Few beam segments pass through more than three main pillars in one structure. Tie-beams are pushed through mortises of pillars and fixed with these pillars by wooden nails and shoulders, aiming at forming a stable frame. Mortises on these pillars must not be too large; otherwise, those through openings would weaken the strength of the structure too much. Thus, the mortises on pillars are usually quite narrow, fitting quite well with the tie-beams. Cutting narrow mortises in different pillars at the same height requires precision in order to allow all tie-beams to penetrate the pillars. The more pillars have to be connected by one beam (and this at several heights), the more demanding the work becomes. Consequently, carpenters had to restrict the number of pillars penetrated by one continuous beam. Otherwise the manufacturing process would have become unsolvable.

Meanwhile, the splicing joints of tie-beams are also weak points under shear forces. The heavy load of granaries standing on a steep slope causes unpredictable structural risks. Carpenters were quite aware of this situation when designing the granaries. Carpenters usually splice two or three segments to one tie-beam. It seems that carpenters avoided having the splicing joints of the tie-beams at different heights all in one pillar. This pillar would then act similar to a hinge and thus weaken the whole structure unjustifiably. For this reason, the segmented connections of tie-beams were distributed to different pillars at different heights. This distribution can be seen in G3, G4, and G5; G2 is a special case that does not follow this logic.

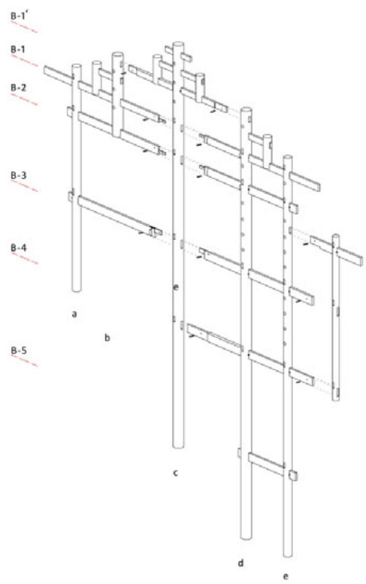


Fig.4.112- a A disassembled *San* of G2

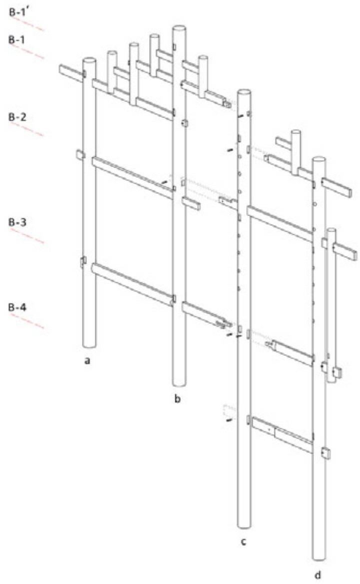


Fig.4.112- b A disassembled *San* of G3

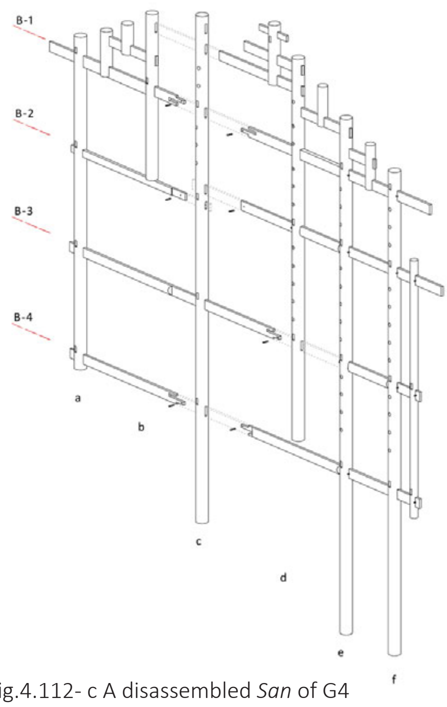


Fig.4.112- c A disassembled *San* of G4

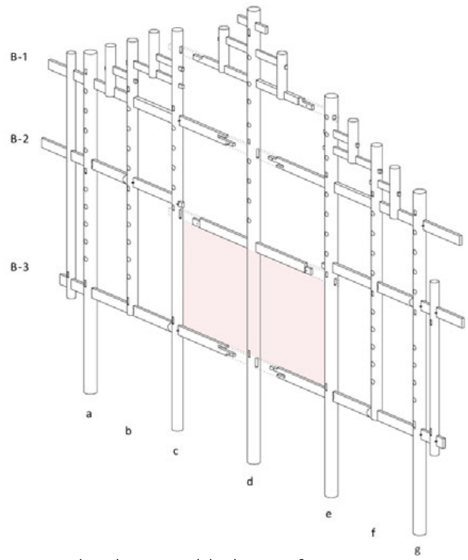


Fig.4.112- d A disassembled *San* of G5

Similar to splicing joints in the longitudinal direction, there are also different types of splicing joints in *San* (Fig. 4.113). Splicing joints used in *San* are more complex, probably due to their task to resist more kinds of forces. Since many tie-beams of *San* also carry the heavy load of stored rice, the splicing joints of these tie-beams need to be against more shear forces. Additionally they need to hold against the large side thrust from stored rice. One special type of splicing joints is usually used in tying the top of rice storerooms. Shown in Fig. 4.113-c, two parts of a tie-beam are jointed to the pillars at different heights. This measure gives way to increasing the section area of the through tenon. Thus it gains stability can against

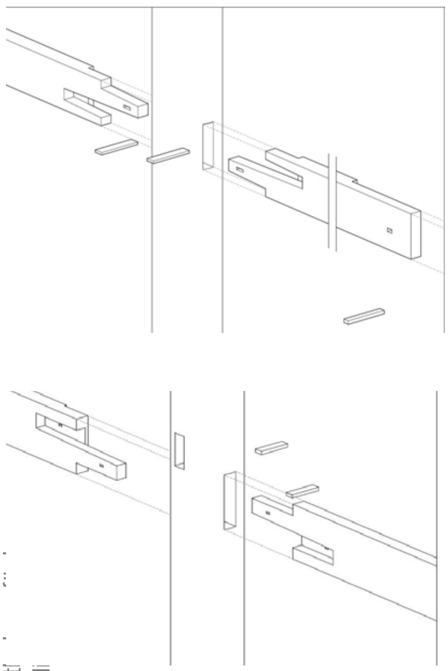


Fig.4.113-a A type of spliced joints in the transverse direction.

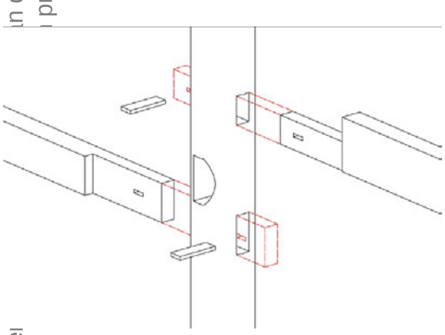


Fig.4.113-b A special type of spliced joints for connecting beams in different height in the transverse direction.

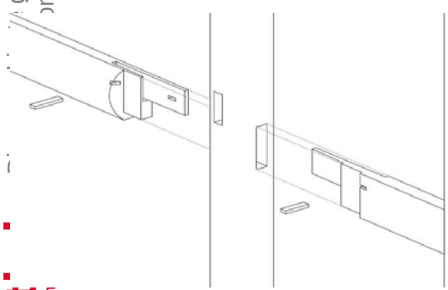


Fig.4.113-c A type of spliced joints for connecting beams with different sections in the transverse direction.

stronger pull forces. This kind of keyed joint is likely stronger than other splicing joints in the transverse direction. It also implies that local carpenters believed that the tops of rice storerooms bear the largest load in a granary. There is only one disadvantage of these joints: the separation of two parts of a tie-beam leads to different height of the top surfaces of these two parts. The consequence is uneven floors above. However, this unevenness is not a substantial problem for granaries.

4.4.2.4 Other building details

4.4.2.4.1 Drying racks

As an important part of granaries of Gaoding, drying racks were usually built carefully. Drying racks of granaries are assembled by horizontal poles resting in corresponding supporting pillars (Fig. 4.114). Generally speaking, most horizontal poles are roughly made from branches or thin logs. They were added to the main structure after it was completed. They can be easily disassembled. Since they are easily damaged by humidity, a problem enlarged by their functional area during the drying process, they needed to be repaired and replaced regularly in the past. Now, most of these poles are missing in existing granaries. Due to the decline of sticky rice production, people have ceased caring about granaries.

4.4.2.4.2 Wall and wooden fences

Accompanying the increase of building scale and the complexity of function, different types of building surfaces are used in the granaries of Gaoding: walls with horizontal planks, walls with vertical planks, wooden fences, and open frontage with railings.

Walls with horizontal planks are typical for enclosing grain storage rooms in Dong areas. Similar to the granaries of Dengcen, they were built carefully. Narrow tapered boards were also used here as the last step of building construction, in order to close the wall tightly.

Compared to walls with horizontal planks, walls with vertical planks are mostly built in a rough way. Their sealing performance is not as good. Thus, they are commonly applied to enclose ordinary indoor areas of granaries. Such as in G2, walls with vertical planks are used in the rear side of the ground floor and at side walls of the building, as a way to prevent people from peeking and entering. They are also usually used as partitions of living rooms and tool rooms in granaries.

Wooden fencing is common wall-enclosing method used when a granary is located close to roads or residential areas. Generally,

Fig.4 114 Drying racks in G2

locals cared more about granaries' security, when their granaries were located close to these places. When they had to build their granary in these locations, they applied different measurements to prevent strangers from entering or coming too close to their granaries. A wooden fence was one of them. It was built mostly surrounding the drying area of a granary: open for necessary air ventilation, yet impeding unwelcome entrants. In granaries built on slopes, fences are mostly added to gable sides. The frontage sides of these granaries are usually kept open, as the heights of their main floors are already far beyond a person's reach.

Generally, wooden fences of granaries were formed by a series of vertical wooden battens installed between beams (Fig. 4.115). For fixing these wooden battens, rectangular shallow holes were cut out along the upside or downside of beams.

Wooden fences attached to the outside of granaries, they were easily damaged by rain. They had to be repaired regularly. Meanwhile, locals lost interesting in former security measurements due to the decline in rice's value over the past 30 years. Many wooden fences are damaged and missed, vanishing step by step.

Fig.4 115 Wooden fences used in a granary in Gaoding.

4.4.2.4.3 Floor and ceiling

In contrast to the Dong granaries in Dengcen, granaries in Gaoding show a significant structural difference. In Gaoding, longitudinal beams take part in carrying floors and ceilings, as is shown in detail sections of G3 (Fig. 4.116). This is a more effective structural feature, and it saves building material, as the number of joists can be reduced.

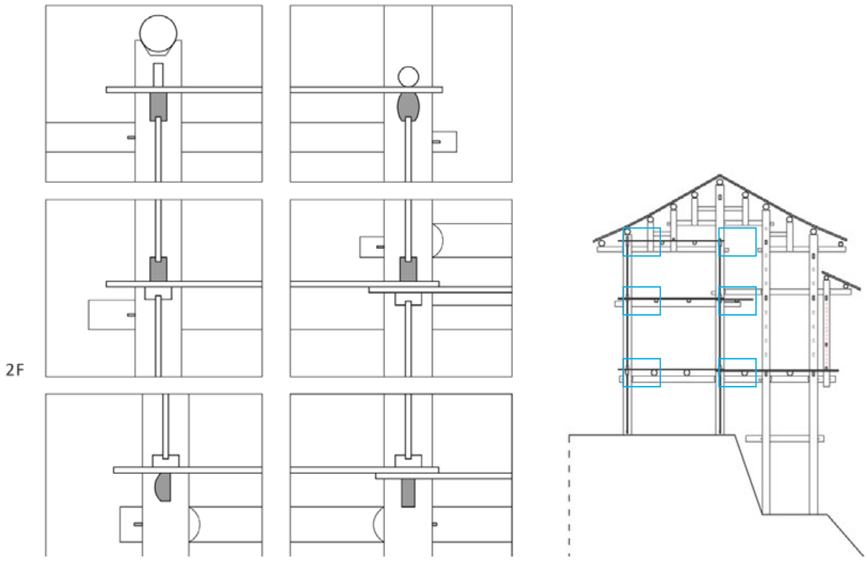


Fig.4.116 Floor construction details of G3

A severe problem remains unsolved, however. The edges of floorboards exposed to the outside are prone to damage from rain under such humid weather conditions. Granaries' rear sides in Gaoding are usually protected from rain in different ways. The main problem occurs at the façade. If the floor boards of the storeroom do not close properly, rice may be lost. Carpenters developed a solution to this problem.

In large granaries, carpenters separated the floors of grain storerooms from the other areas. Thus, two areas of floorboards are at the same level: one area is prepared for the rice storerooms, the other for the passage. The two areas usually overlap beneath the front wall of storerooms (Fig. 4.117). Boards covering the storeroom's floor do not remedy the immediate damages. Repair work and maintenance work on the separate floorboards can be executed independently.

Fig.4.117 The overlap floors beneath the front wall of storerooms.

Both floors and ceilings of granaries are composed of 3-cm-thick wooden planks with tongue and groove joints (Fig. 4.118). As the tongues and grooves are delicately shaped, we must assume that they were made with fine special tools.

Fig.4.118 The floors of granaries are composed of 3 cm thick wooden planks with tongue and groove joints

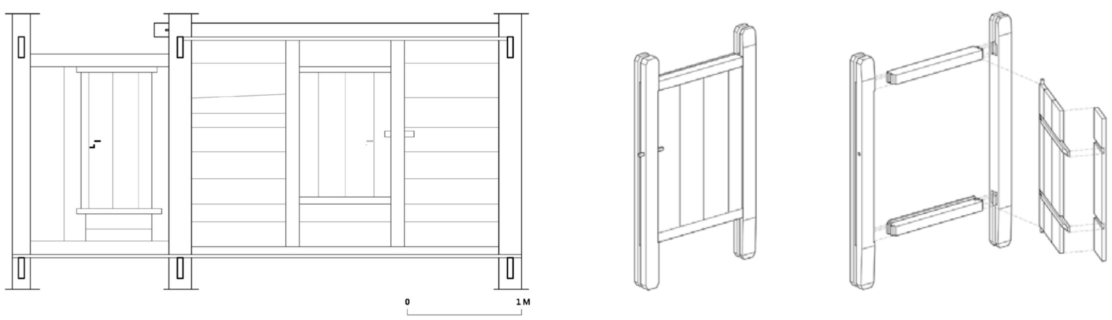
4.4.2.4.4 Entrance and doors

Owing to large the building scales of many granaries in Gaoding, nearly all granaries have entrance doors. These entrance doors are used to prevent strangers from entering or even snooping around interior spaces of granaries. Stored items in storage rooms and drying spaces are directly related to their owners' private wealth. Generally, villagers have tried to hide the entrances of their granaries in inconspicuous places, such as the rear side of a granary or in a corner of the ground floor. In some cases, they set obstacles into granaries' entrances. Taking G1 as an example, they intentionally left a deep moat between granary and an earthen slope as a natural barrier. Only by putting wooden planks over this moat, can people enter the granary. The entrance staircases of some large granaries are located on their ground floors. Some are even enclosed with wooden planks, as a measure to stop snooping.

Some large granaries have more than one entrance door. Both G3 and G4 have two doors. The remaining half part of G5 also has two entrance doors, one on the ground floor in the front and the other one on the first floor at the rear side. Separate entrances indicate that each of these storage compartments belongs to two or more families. It can be related to the convenience of rice transportation as well.

Inside a granary in Gaoding, we commonly find two types of doors: (1) doors into tool rooms and (2) doors into rice storerooms. Due to their different functions, the doors look differently and have different sizes. Openings into tool rooms are usually narrower. Their threshold is also lower than of the rice storerooms. The average threshold height into rice storerooms is around 50 cm (Fig. 4.119).

Fig.4 119 Two types of doors applied in granaries of Gaoding



A rice storeroom's door frame is simply assembled by four members (Fig. 4.120). The two vertical members are installed into the topmost and lowest horizontal wall boards by forked ends, thus promoting the door frame to be fixed with the wall. The door leaf was assembled by several wooden boards, connected by two perpendiculars fillets housed in dovetailed trenches.

They commonly apply double security measures in order to lock the doors in Gaoding. One of these measures is simpler: They use a wedge to fix the door leaf with the frame. The door is opened by kicking out the wedge with a wooden mullet. Opening the door produces loud noise, alerting the village that a storeroom has been opened. This simple thief-prevention method is widely used in villages of Guizhou and Guangxi. Another locking method is more complex. Usually, a special wooden lock appears on the rear side of the door. This lock can be opened only by keys. The production of such locks requires skills and experience. The production of locks also marks the advanced of craftsmanship in the region. Nowadays, ordinary padlocks are widely applied for locking the doors replacing traditional wooden locks.

4.4.3 Variation and change

Due to the general decline of rice output and the reduction of sticky rice planting areas in recent decades, many locals have already abandoned their traditional granaries. The promotion of the new storage method helps to speed this process. Instead of independent granaries, some locals now store their harvests in plastic bags on top of their own dwellings. Steel silos were also introduced into the villages in recent years, another factor that has made people abandon their wooden granaries (Fig. 4.121).

The importance of traditional granaries has declined. Some were demolished to reclaim the timber and building sites. Some were abandoned and not maintained. Most of the traditional granaries are now surrounded by newly built dwellings, withdrawing the pressure of imposed by the lack of building sites in the village.

Fig.4.121 A modern steel silo location in the ground floor of a new dwelling, Gaoding.

Wooden Granaries in Southwest Yunnan

5.1. Background

5.1.1 Cultural history, climate and t-opography

Southwest Yunnan region is a remote mountainous region situated on the Southwest border of China, bordering Myanmar. (Fig.05.1) Due to its remote location and geographically complex terrain, it used to be a kind of non-governed area until the late 1950s. It is one of the most multicultural regions in China. A variety of ethnic groups live in this region: Dai people（傣）[1], Lahu people（拉祜）[2], Wa people（佤）, Pulang（布朗）and several more.

Among these ethnic groups, the Pulang and the Wa belong to the same linguistic group: Mon-Khmer. Thus they share some similar characteristic habits: Upland Rice cultivation, settling in the mountainous area at altitude around 1500 meters and so on. Furthermore, based on field investigation and literature records, their building technologies also show some similarities: 1) the dwellings of these two ethnic groups are all wooden pile dwellings[3], 2) The original carpentry tools of them are also similar, as well as their building materials（李明富，1998, p7; 街顺宝，2009, p42).

However, there are also several differences between these two ethnic groups. Pu lang people largely inhabit in Menhai and Menman areas, more close to the southern valley region, which mostly occupied by the Dai. In the history, Pulang villages used to be under the rule of the Dai lords for 150 years until the 1950s. Thus they were more influenced by Dai culture, concerning from religion to building technology（街顺宝，2009, p44). The major of the Pulang are Buddhists.

The Wa traditionally settle down in the Awa mountain area[4], consisting of nowadays Lingchang in China and Wa Special Region in Myanmar. They largely lived in remote mountainous area without unified government until the late 1950s. Different with the Pulan, Wa people traditionally hold an ancient animism belief, which centered around various types of ritual blood sacrifice. In the past, the most important annual ritual for the rice harvest originally should immolate heads, which came from strangers killed in 'headhunting'（徐志远，2009, p52). And this usually developed into the

1. Dai people（傣族）also refer to the Tai people.They are scattered through much of South China and Mainland Southeast Asia, with some (e.g. Khamti, Ahom) inhabiting parts of Northeast India. Tai peoples are both culturally and genetically very similar and therefore primarily identified through their language.

2.The Lahu people（拉祜族）are an ethnic group of China and Mainland Southeast Asia.

3. pile dwellings can be also refer to *Ganlan*（干栏）buildings. They are buildings supported by posts, with a raised floor.

4. Awa mountain（阿佤山）also Ava mountain, straddles the border of northern Myanmmar and China. The majority of the Wa people live in Awa.

Fig.5. 1 Location of Yunnan province and Guangxi province in China

mutual vendetta between the villages, thus Wa people traditionally were forced to focus on the defense of villages and dwellings.

Located among the subtropical highland and humid subtropical zone, the local climate of Southwest Yunnan is mild and humid.The rainy season of this region lasts from May to October, while the heaviest rain occurs between June and August(李明富, 1998, p 59).

The local terrain is mostly mountainous, with elevations from 550 meters to 2605 meters (李明富, 1998,p54). The varied and rugged terrain causes slight climatic difference from high places to lower valley areas. The valley bottoms are most hot and humid in these mountainous regions, while the mountaintops are mainly cool and dry, due to the cold breeze in the high places.

Although the mild climate of this region is good for rice cultivation, its rugged terrains restrict the area of local arable terrains. The limited fertile and irrigated lands located in valley bottoms are mostly occupied by Dai people for planting water rice. Meanwhile, some other ethnic groups such as the Wa and the Pulang had to search a way to live on the barren slopes in mountainous areas. Hence, upland rice, which can adapt to dry land well and which provides a higher yield than other original crops, became the major crop for the Wa and the Pulang in this area.

5.1.2 Cultivation and harvest of upland Rice in Pulang and Wa areas

Slash-and-burn agriculture had still been widely applied among Pulang and Wa villages, until the 1980s (蔡鹏顺, 1997,p162). Pulang and Wa villages mostly are situated in tropical mountainous areas with abundant forest resources. However, the soil quality of these areas is largely not as fertile as of the lowland areas, thus people needed to use ashes of burnt trees as a necessary fertilizer for planting upland rice. As Delang describes in his work:' much of the nutrients necessary to grow crops are in the vegetation rather than the soil, and are released in the form of ashes when trees are burned' (Delang, 2012, p1).

There were two types of shifting cultivation methods carried out among Wa and Pulang villages: one was without rotation technology, the other relied on rotation technology(尹绍亭, 2000,p58,60). In non-rotation cultivation, the field was left fallow immediately after the first year's harvest. In shifting cultivation with rotating cultivation, farmers would continue planting on the same field for two to three years. And they changed species of the planting crop every year during this period. Nevertheless, no matter which types of shifting cultivation local farmers applied, according to their tradition, rice can only be planted once on the same field during a shifting round[5] .

5. A shifting round: A shifting round is the period between the first reclamation of a field to the next planting. It varies from one place to another place. It can cost 3-11 years.

Most of the Wa or Pulang villages of Yunnan had already been established in the same places for over one hundred years. This means that they carried on shifting cultivation in the same fields during this period. Aiming at maintaining the fertility of these fields under this exhausting agricultural method, they developed a kind of rotational cultivation. In this method, headmen of a village would firstly divide the surrounding fields into several equal sections. The number of sections usually differs from place to place, between seven and eleven. Then all villagers would plant crop together on one section of the field in one year or some years, and shift to the next section. This process was continually repeated among different sections until all sections of their field had been slashed and planted once. Then they would restart to do slash-and-burn farming on the first section again.

With this agricultural arrangement, each field can fallow six to ten years after tillage. During the fallow period, cogon grass (*Imperata cylindrica*), bamboo and trees would naturally grow on these fallow fields. Wa people sometimes also plant alder trees (*Alnus cremastogyne Burk*, Chinese: 水 冬 瓜) in their fallow fields, as alder trees can recover the fertility of the fields (尹绍亭 , 2000,p220). Some of these plants would be utilized as building materials, and some would be used as daily firewood.

Due to the local traditional farming method, the average yield of the upland rice was generally lower than the normal rice: around 85 Kg/*Mu* (蔡鹏顺 , 1997,P165). In avoidance of starving, a family of 4 people needed to farm at least 20 *Mu* field in a year. If the local fallow period is seven years, this means that the family should occupy at least 140 *Mu* field to meet their basic consumption. Accordingly, the total field amount of a Wa or Pulang village is generally much more than a Dong or Han village. Meanwhile, the size of a Wa or a Pulang village is usually smaller than a Dong or Han village.

The shifting cultivation steps of upland rice in Pulang and Wa villages largely should be done sequentially in certain terms of a year. In January, farmers firstly slash the plants on their field. And they burn these fallen trees in March. The sowing work traditionally was carried out in May, then rice would be mature in late September (李明富 , 1998,P85).

The traditional harvest process of upland rice in Pulang or Wa villages is different to the harvest process of ordinary rice . One main reason is the total area of the field owned by one Pulang or Wa family was generally larger than that of an ordinary Han family. The other reason is that the timing for reaping the upland rice in this region is different from the ordinary rice. Pulang or Wa farmers usually start reaping several days after rice matured, while Han and

Fig.5. 2 People used bare feet and wooden sticks for threshing rice in the field in the past. (source: 徐怀学)

Fig.5. 3 People used big fans for winnowing rice in the past. (source: 徐怀学)

Dong farmers reap rice as soon as rice matured. The Pulang and Wa believe that it will be easier to reap rice when the rice getting dry in the field.

Reaping: (Fig.05.2) Farmers reap rice, and then stack all rice ears together in the center of their field. They leave the rice ears stacks drying under the sun for several more days. During this period farmers would mostly stay in the watching pavilions located in the field, in order to guard their harvest.

Threshing: When they detected that the rice ears had reached a certain degree of drying they began to lay bamboo mats in the center of the field, and threshed the rice by their bare feet or by wooden sticks (蔡鹏顺 , 1997,p170) The threshing process would usually last for two days.

Winnowing: (Fig.05.3) after threshing, farmers traditionally used big fans for winnowing in the past. When the kernels finally get dry and clean after these series of steps, women would carry them back alone to the village and directly store them in granaries (蔡 鹏 顺 , 1997,P170) .Some families would also use cattle for transportation.

Drying:in the previous steps, cereals had already been dried to a certain degree under the sunshine in the field. In the related records, rice seems to be put into granaries immediately after they were carried back to the village. In some photos, we can find locals also dried their rice on the drying platform. It is hard to be sure whether these were occasional cases in rainy season or it was a must step in the whole traditional harvest process.

Traditionally, locals hulled rice every morning with wooden pestles and mortars. The wooden mortars were largely located in the ground floor of the dwellings, some were located in the places next to the doors of the houses.

After the 1960s, more and more advanced agricultural implements were introduced to Wa and Pulang villages. Additionally, the traditional shifting cultivation method at that time was thought to be a backward production method causing a great waste of natural forest resources. Thereby local government made a lot of efforts to persuade local Pulang and Wa people to give up their traditional shifting cultivation. At the same period, the normal rice species was also widely introduced to this region due to their higher yield. Accompanying with this, the irrigation technology and terraced field technology were also introduced to offer necessary planting condition for normal rice. As a result, traditional shifting cultivation of upland rice has almost vanished in the 1980s. Farmers did not slash and burn their fields every year any more. Meanwhile, fallow fields were replaced by continually cultivated fields or economic woods. This caused a variety of changes in the local farmers' lives, including their building techniques.

5.1.3 Forestry and carpentry technology of Pulang and Wa people

5.1.3.1 Forestry Resource

There is an abundant variety of vegetation growing in the surrounding areas of Pulang and Wa villages due to the mild subtropical climate. For local construction projects, there used to be two types of plant resources - natural forest and fallow field - where they got their building materials from. The local natural forest resources of these areas mainly include tropical evergreen broad-leaf forests and coniferous forests. Fallow fields produce shrubs, cogon grass, bamboo, and fast-growing evergreen trees in the past. When locals needed large timbers for construction projects, they got them from natural forests. Meanwhile, they obtained most of smaller timbers, bamboo and cogon grass from fallow fields.

5.1.3.1.1 Wood

In Pulang and Wa villages, most of the traditional buildings' frameworks, including their granaries, are made of wood. Generally, chestnut wood[6] , alder wood (*Alnus cremastogyne Burk*, Chinese: 水冬瓜）and schima wood(Latin: *Schima wallichii,* Chinese: 红毛树，木荷). are mostly selected as construction materials. All of them are hard wood. Chestnut wood is usually considered to be the best timber for the main structural members of buildings, due to its hard texture (街顺宝，2009,p110). According to local tradition, pillars are the most important construction components in a building, especially the two central holy pillars of the dwelling. The importance of pillars got locals to select strong and durable timbers for these pillars. The Pulang only used chestnut wood to produce pillars in the past (街顺宝，2009,P110). Wa people also regard chestnut wood as the best building material. But they also accept Schima wood for the same purpose, when they cannot find large chestnut wood. On the other hand, Wa people owned some more requirements for central pillars, such as that the trees used for future central pillars should be strictly straight. According to their tradition, applying timbers from fork-shaped trees in dwellings would bring misfortune into the family (陈卫东，王有明，1999,p8-10).

However, in order to get larger timbers, they needed to go to the original forests far away from the village. The logging used to be a big event for the whole village in the past, due to limited transportation conditions. Meanwhile, locals mainly cut small timbers in surrounding fallow fields in the past. They were mostly

6. There are three species of chestnut wood (栗木）mostly applied in the local construction. Their Latin name are: *Lihtocarpus magneinii, Lihtocarpus baigiangensis, Castanopsis diversifolia.*

alder woods and other fast-growing woods(尹 绍 亭 , 2000,p223-225). Since trucks and machine saw were imported in this region in the 1980s, and road constructions were done, the difficulty of getting big timber had been reduced.

5.1.3.1.2 Bamboo

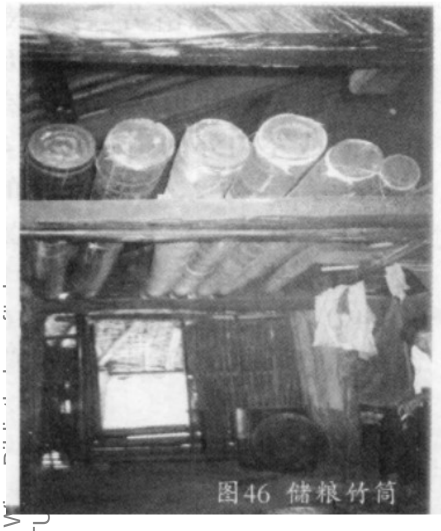


Fig.5. 4 Large bamboo stems for storing rice in the roof structure of a traditional house. (source: 韩军学 ,2007, p. 87)

Bamboo is another common material widely used in buildings of Pulang and Wa villages. Compared to ordinary trees, bamboo grows much faster, thus can be obtained effortlessly. Local people mainly plant bamboo artificially in areas surrounding the village, including in their fallow fields.

There is a special bamboo species called Dragon bamboo (*Dendrocalamus sinicus Chia et J.L.Sun,* Chinese: 巨 龙 竹) grown in Southwest Yunnan regions. This Dragon bamboo is the largest known bamboo species, the general diameter can exceed 30 cm. It is used to make containers, rafters, and bamboo mats (Fig.5.04). For some simple building tasks like drying platforms and small Pulang granaries, it even can act as a main structural material.

Traditionally bamboo mats used to be widely applied as walls and floors in Pulang and Wa dwellings in the past, before the wide application of the machine saw in the 1980s. There are two types of bamboo mats: woven bamboo mat and non-woven bamboo mat. The non-woven bamboo mat is made by pressing the whole bamboo stem into a plain. It is stronger than the ordinary woven bamboo. After the 1980s, the use of bamboo mats decreased, since cutting timbers by the help of machine saw became a much easier work.

5.1.3.1.3 Cogon grass

Cogon grass used to be the main roof material in these regions before the 1980s. Locals usually cut and collected cogon grass in their fallow fields. And women weave these grasses into pieces of grass mats and dry them in shady places for the next necessary roof reparation work. This was part of their daily life. However, thatched roofs gradually vanished during the past 40 years. The situation is largely related to the following two reasons: 1) Vanishing of the fallow fields during the past 30 years increased the difficulty to obtain thatch. Many farmers therefore have to look for an alternative. 2) The introduction of tile and asbestos roof coating significantly extends the life time of roofing. Since the new material frees locals from the troublesome regular roof renovation work they decided to renounce the use of thatched roofs.

Wending village became the only exception in this area. The inhabitants of this village are asked to continue using grass to cover their roofs since the preservation rules force this village to maintain the so called traditional Wa home style. Aiming at solving the shortage of cogon grass, local government arranged to import cogon grass from a neighboring country Laos(唐黎洲, 2017,p94).

5.1.3.2 Carpentry technology

In the last 50 years, the building technologies of the Pulang and the Wa villages of this region have undergone a dramatic change. A determining factor is the change of the carpentry tools.

Before the 1980s, Pulang and Wa people generally used similar types of simple carpentry tools in their construction works in the past. Most of them appeared rough and little sophisticated: long-handle axes, short-handle adzes, chisels and long knives (Fig.5.05). Among them, long-handle axes were the main tools for cutting. Local Pulang and Wa people mostly used this tool for felling trees and shaping timber components. Short- handle adzes were used for smoothing the surfaces of the components, and chisels were used for producing grooves and mortises. Long knives are still everyday tools for Pulang people nowadays. They were traditionally used it to trim the edges of wooden planks.

The saw was first introduced in Pulang villages in the early 1960s by Dai people. Before the introduction of the saw, wooden or stone wedges were used for tree conversion (汪宁生, 2001,p150；街顺宝, 2009,p42). This primitive method had been already invented and widely applied in different regions in Neolithic period. Yang Hongxun speculated it should have been done actuated in this way: workers firstly kicked a series of stone or wooden wedges along a longitudinal line into the felled trunk, and then hammered them deeper into the log. By this action, the log split into two halves. Workers then used axes or adzes to shape the halves into planks. (Fig.5.06) (杨鸿勋, 1987,p62). The whole process had to be carried out by experienced carpenters. However, this method causes strict limitation in producing wooden planks as straight growing trees with little branches can be used. Otherwise the thickness of the planks can be uneven. This can also explain the Wa's strange

Fig.5. 5 Carpentry tools of Pulang people.(source: 街顺宝, 2007, p. 87)

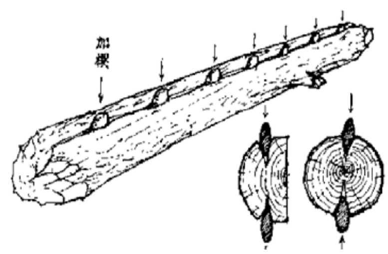


Fig.5. 6 Stone wedges were used for splitting logs in the Neolithic period. (source: 杨鸿勋, 1987, p. 62)

logging tradition mentioned before: only very straight trees with few branches can be selected for construction, and the trees with Y shapes are seem to be unlucky material. And it can also imply that the timber used for producing wooden planks should be grown in natural forests in the past. As tree grown in fallow land are rarely as straight as tree grown in natural forests.

Due to the limitation of tree conversion and the difficulty of the transportation, wooden planks could only be found in some high-rank dwellings or some granaries in Wa villages in the past. For common houses, local Pulang peoples and Wa peoples found an alternative material for enclosing the building frameworks: bamboo mats. Bamboo are much easier to obtain than wood. In the past, only high status houses, including headmen's dwellings and granaries, were built with wooden planks.

The saw might arrived in Wa villages in later period. This led to a big change of building technology in this area. Dai people also imported some other 'advanced' carpentry tools such as broad axe and plane at that time. But it had not been widely applied in building construction until the 1980s. The same change occurred in Wa villages. However, due to the different local policy, the results of these alterations varied in Pulang and Wa villages.

5.1.3.3 Building process

Apart from the carpentry tools, there are more influential factors on the building process that had changed building in these areas, particularly the method of erecting buildings.

The whole traditional construction process of Pulang and Wa buildings can be divided into the following steps:

Fig.5. 7 Long-handle axes were used for logging tree in Wa villages in the past. (source: [illegible],2009, p. 31)

Logging: With similar tools, the traditional logging period of the Pulang was different to the Wa. Pulang people usually fell trees in November, while Wa people mostly cut trees in September (街顺宝, 2009,p111; 石磊, 2008,p15-18). This can be related to their different religions. However, the two ethnic groups share the same taboo related to the process of felling trees. And they all emphasized the direction to which the tree had to fall when being cut. If a tree fell in an inappropriate way, such as that the felling tree got caught by a neighboring tree, it would be thought to be unlucky and should not be used in construction anymore(Fig.5.07).

Wood Drying: After logging, trunks usually were piled in the mountains until several days before the selected construction date (街顺宝, 2009,p111). The drying period would usually last two to four months. Trunks would be mostly cut into intended lengths before transportation, aiming at reducing the difficulty of moving.

Transportation: The timber transportation was usually a big event in villages of mountainous areas, due to the difficulty of pulling long and heavy logs through dense jungle. It mostly needed a great number of men to engage in this activity. In Pulang villages, it usually needed 20-30 people to carry trunks back to the village(街顺宝, 2009,p111). It was almost the same in Wa village (徐志远, 2009,p31-33).

Building construction: According to local tradition, the erection or renovation work of the granary should be done before rice harvest period, occurring around September. An additional taboo concerning construction work of granaries in Wa villages was that a family should not build their dwelling and granary in the same year, otherwise it would bring misfortune to their home.

According to field investigations and literatures, the Pulang and Wa use different granary structural forms, and their building construction methods also shows some differences.

Before the 1980s, most of Pulang people used earthfast method(栽柱造)[7] to build their houses: dug holes to erect post for supporting their house. This method was used with granaries alike. Since the introduction of Dai building technology in the 1980s, locals began to put pillars on the stone bases in the construction works. This led to great changes occurring in the building erection process.

For erecting a building carried by earthfast -posts, Pulang people usually carried out the following steps in the past (韩军学, 2007,p117-120):

i. Select a proper building site before the erection day. Dig out several rows of holes in the ground. The number of the holes reflects the intended size of the building.

ii. Then insert all posts into these holes. In the building tradition of Pulang and Wa people, the two central holy pillars should be erected first, then followed by the other (石磊, 2008, p15-18; 街顺宝, 2009,p113). Buried posts can stand independently without additional supports.

iii. In the next step workers linked beams to the posts to form the main framework and add the roof structure on top.

iv. Cover the roof with grass or tiles.

The construction process in a Pulang village was done in a different way, when pillars of the house were based on stone foundations (街顺宝, 2009,p117-120).

7. It also called post in ground construction.

i.	Rough grading works should be done firstly, after selecting a proper site.

ii.	Put foundation stones on their intended places.

iii.	Connect the pillars and beams to form simple trusses.

iv.	On the selected day of erection, a lot of people, most of them were relatives or friends of the owners, came to help to erect pre-assembled trusses one after another, and connect them with beams in longitudinal direction.

v.	Cover the roof with grass or tiles.

Fig.5. 8 A Wa granary with reused wooden members.

Different to Pulang people, the Wa traditionally applied earthfast posts to support their dwellings. They use only pillars with stone bases in the granary construction works. This also led to some differences between the erecting processes of dwelling and granary.

Reparation and renovation: In order to prolong life time of a house built with earthfast posts and to save timber materials, locals developed a unique building tradition. Houses had to be dismantled every 5-10 years and to be rebuilt again. In the rebuilding process, people would check firstly the condition of the main timber structure, and replace badly rotten members with new members. The two holy pillars should be replaced with new material as a rule, whatever they got rotten or not. The roof part, including the rafters and the grass mats should be renewed totally. This tradition is not only carried out among dwellings, but granaries as well. According to my field investigation, locals usually would not simply throw away those rotten components, but they would cut off the rotten part and reuse still useable material in other places (Fig.5.08).

5.2. Pulang village: Zhanglang

Traditionally, there are two types of rice storing containers used in Pulang villages: indoor baskets and independent granaries. It is said that most families stored their rice in bamboo baskets in their house, due to the low yield of highland rice and security considerations. Since 1970s more and more Pulang families began to build independent granaries (街顺宝，2009,p53).

5.2.1 Village, dwellings and granaries

Zhanglang, a large Pulang village with a population around 1000, is located on a mountainous area in southern Yunnan Province, closed

to the border between China and Burman. This village is one of the most ancient villages in Menghai area. Tea product is the main industry of this village nowadays. Local farmers plant rice only for their own daily consumption.

Fig.5. 9 The satellite map of Zhanglang village, Menghai , Yunnan.

Fig.5. 10 A current Pulang dwelling

Located on the southern slope of a mountain at an altitude of 1500 meters, the village is surrounded by a circle of trees (Fig.5.09). Beyond this tree circle, there are vast fields belonging to the village. The trees form a kind of defensive enclosure around of the village and also help to prevent soil erosion. There are three village gates along the village border. They acted as the only entrances into the village. Along the village border, locals built three groups of granaries inside the village.

Pulang dwellings are mostly 'one-family houses', built for nuclear families. Some families also live with their old parents. Pulang dwellings are pile dwellings, supported by pillars with stone bases. The current dwelling form is thought to be quite different compared with the former dwellings, due to import of new building technology brought by the Dai in the 1980s. (Fig. 5.10) According to literature, the former Pulang dwellings were much smaller and cruder than the current Pulang dwellings. Most former dwellings were supported by only nine earthfast posts equipped with woven bamboo walls and floors, and covered with thatched roofs (街顺宝, 2009, p51). However, the new building technology changed local dwellings' forms. Pulang dwellings built after the 1980s largely own much bigger interior plans. The majority of them consist of more than 40 pillars. In addition, walls and floors of the current dwellings are all assembled by wooden planks instead of woven bamboo, due to the introduction of saw(Fig.5.11).

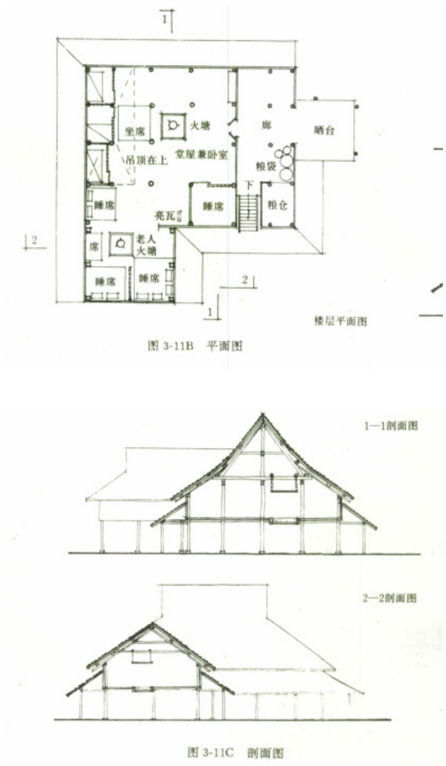


Fig.5. 11 Plan and sections of a Pulang dwelling. (source: 王翠兰 ,1993,p53)

However, the general spatial function arrangement of the local dwellings does not differ too much from the former ones. Generally, each dwelling is equipped with a drying platform, attached to the lifted entrance area of the dwelling. The place is used for drying rice during the harvest period (Fig.5.12). In the interior area, the

Fig.5. 12 The platform for drying rice. (source: 张原 ,2005 , p. 16)

Fig.5. 13 A group of granaries located outside the village.

fireplace defines the core of the house providing heating and serving as cooking and thus gathering place. Most of the family activities happen around the fireplace, including eating, sleeping and talking. The couple usually have their own room, which separated from the open living space by a wooden wall. The opening ground floor of a dwelling is a comfortable semi-outdoor space, mostly used as a multifunctional working place for weaving, rice milling and so on. Some locals would also close this place with bamboo fence, for raising chicken.

In order to decrease fire risk the granary of a family would mostly be built in a place far away from the dwelling. In Zhanglang, there are three groups of granaries situated at different places along the village border (Fig.5.13). One of these groups of granaries is even outside the village gate. In Pulang’s tradition, an ideal granary location should be a place in sunlight. Thus many granaries were built at higher places on the slopes.

Fig.5. 14-a A six-pillar granary

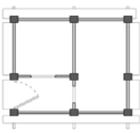


Fig.5. 14-b A nine-pillar granary

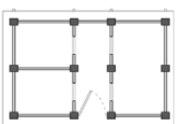


Fig.5. 14-c A twelve-pillar granary

5.2.2 Granary and its construction

Based on field survey, nearly all existing granaries of Zhanglang were built in the 1980s, the period when the Dai people introduced new building technologies in the village. Thus they own similar characteristics with the dwellings: pillars on stone basements, wooden plank walls, tile roof. Only some appear differently. They have bamboo framework and bamboo walls.

Traditionally locals classify granaries by the number of their pillars. There are three common types of granaries existing in Zhanglang: six-pillar granaries, nine-pillar granaries and twelve-pillar granaries (Fig.5.14). The nine-pillar granary is the most common type in Zhanglang, and the following section presents the examination of such a typical Pulang granary.

The selected granary is a typical nine-pillar granary. It located on

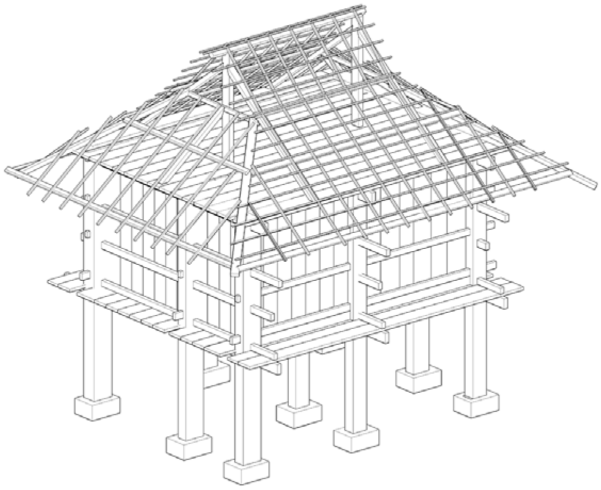


Fig.5.13

Fig.5.14

Fig.5. 15 The 3D-model of the selected case

Fig.5. 16 The selected nine-pillar granary

a small terrace on the northern slope in the village. (Fig. 5.15, 16) It was built in the 1990s, with a maximum capacity of 5000kg. The square plan of the granary consists of two storerooms and one short indoor passage. There is a door enclosing the indoor passage. This outdoor provides an additional barrier next to the inner doors connecting the storerooms(Fig.5.17).

The floor of the granary is elevated 1.3 meters above the ground due to the need for ventilation. We might assume that this elevation additionally served anti-theft and rat roof-proof. A removable access is essential for entering such a granary. Locals generally use movable short wooden ladders, which can hung to one side of the granary when not in use. Applying a movable ladder in a granary offers several advantages: 1) a removable ladder is protected against deterioration if otherwise constantly exposed to rain.2) Rats lose a too simple path into the granary.

According to the examination the granary is assembled of the following parts: a main framework, walls, ceiling and floor, roof, door(Fig.5.18). Mouse-guards are found in some granaries. They are made from corrugated metal plates or prickly branches now.

5.2.2.1 Framework

The framework of the Pulang granary appears quite unusual. It is assembled by nine pillars and several layers of horizontal wooden components(Fig.5.19).

A detailed study reveals that these horizontal components can be classified into two types: load-bearing beams and reinforcing sticks. The topmost layer of beams and the lowest transverse beams are load-bearing elements executed in big dimensions. The remaining horizontal members are built in originally to hold the inner wall planks.

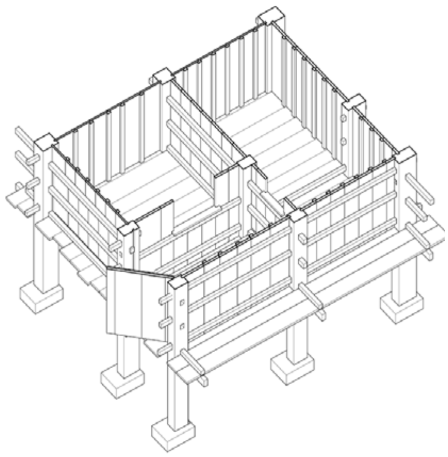


Fig.5. 17 The inner spatial division of the granary

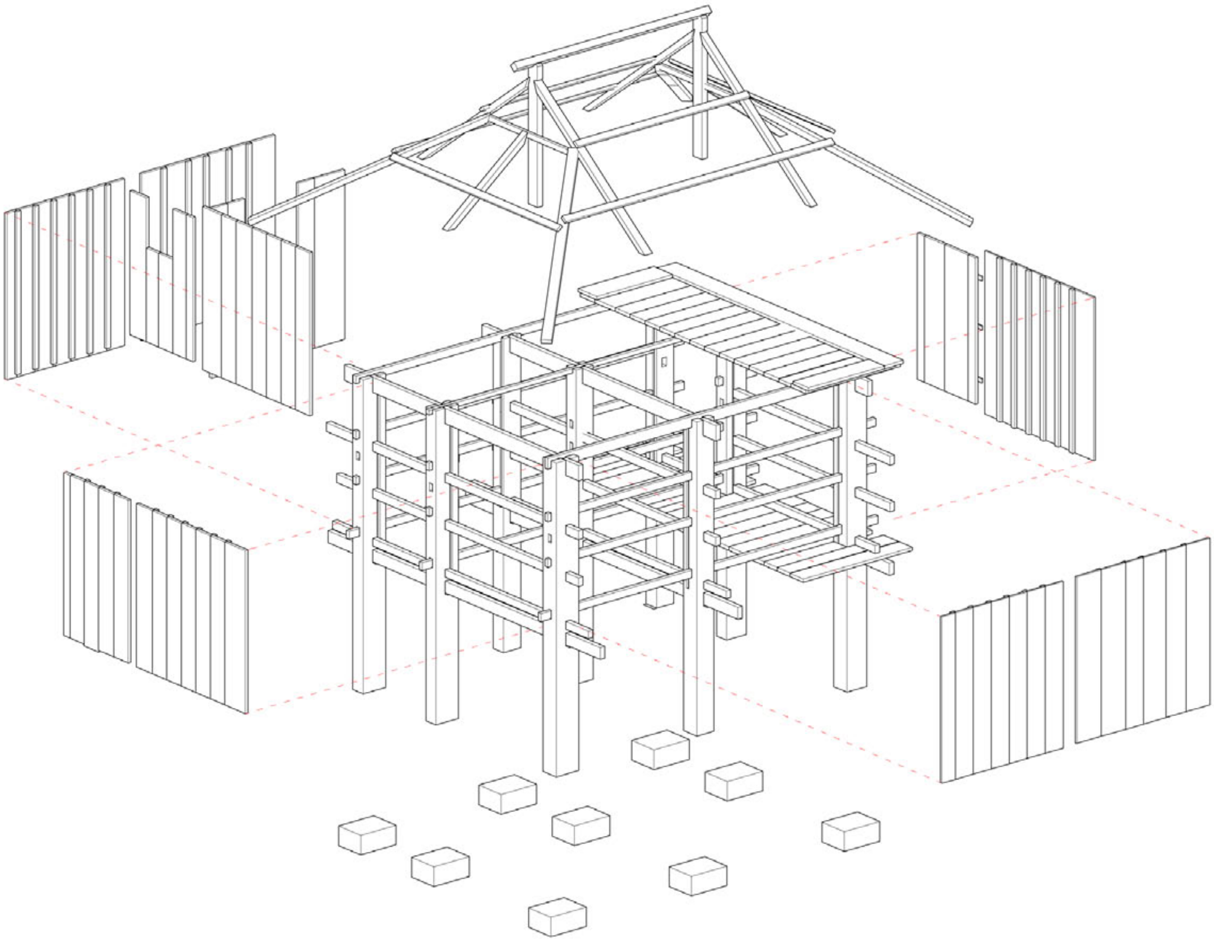


Fig.5. 18 The granary is assembled of the following parts: the main framework, walls, ceiling and floor, roof, door.

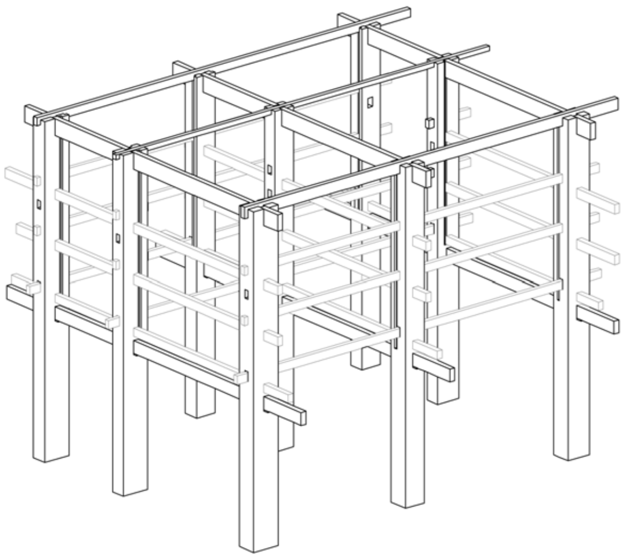
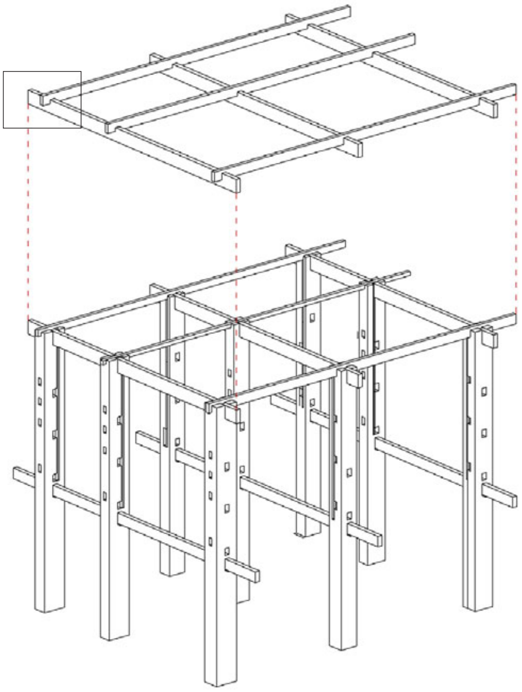


Fig.5. 19 The framework of the granary



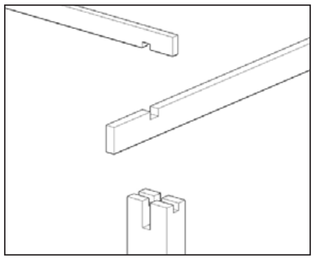


Fig.5.20

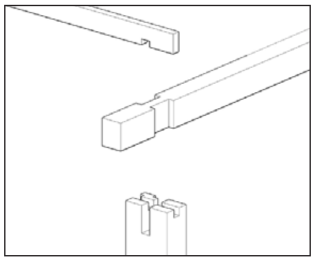


Fig.5.21

Fig.5. 20 Tops of pillars of the granary are fixed by the topmost layer of beams。

Fig.5. 21 Carpenters applied thicker timbers for lower transverse beams, and cut necks out of these beams, in order to keep the lower pillars in place.

One of the main problems in building a granary framework is the analytical condition how to resist side thrust. Side thrust triggered by the inner rice heap is the main reason of structural deformation. Accordingly, carpenters developed various ways for strengthening the structure against side thrust. One common way is the application of keyed joints to anchor beam and pillar, which is widely used in Dong or Miao peoples' granaries. Pulang carpenters developed two other different method to connect vertical and horizontal components apart from keyed joints.

Tops of pillars of the granary are fixed by the topmost layer of beams(Fig.5.20). This topmost layer of beams consists of three longitudinal beams and three transversal beams, connected to a wooden grid by cutting simple cross-lap joints (Fig.5.22).By installing this wooden grid into the forked top ends of the pillars, their upper ends are fixed in their intended positions. Compared to the keyed joint , this method of connection is simple and can be done with fewer tools. However this type of connection is weaker than the ordinary keyed joint. Aiming at strengthening this kind of joint, some carpenters chose to modify the beams. One development is that they applied thicker timbers for lower transverse beams, then cut necks out of these beams, in order to keep the lower pillars in place. Another alternative is the application of keyed joints in the lower beam. Both treatments are mainly for preventing pillars from tilting outwards, which is the common deformation risk of granaries.

In the lower part of the framework, the lowest transverse beams are pushed through the pillars. Wedges were added in between

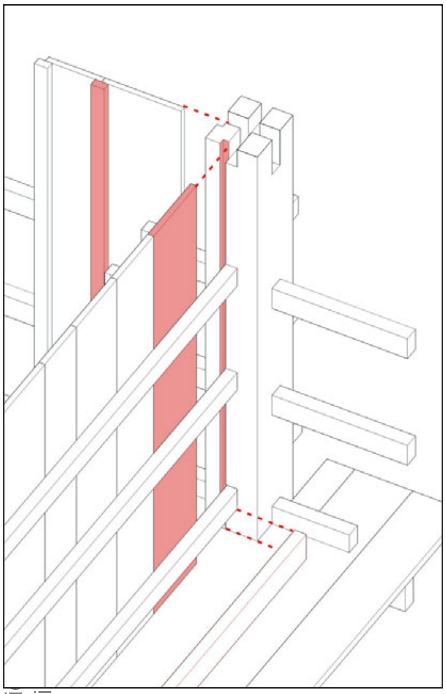


Fig.5. 22 The wall construction detail.

Fig.5. 23 A granary with the bamboo structure in Zhanglang.

the beams and pillars, aiming at tightening these connections. Meanwhile, longitudinal tie beams seem to be absent in the lower beam layer. According to a closer examination of details, it can be found that small wedges are inserted in between the reinforcing sticks and the holes in the pillars, thus fixing all sticks and pillars tightly together. This suggests that local carpenters try to use this way to turn these reinforcement sticks into tie beams. Connection secured by wedges are weaker compared to keyed joints. Yet resistance force can be increased when there is quite a number of connections along reinforcing sticks that are secured by wedges.

5.2.2.2 Wall

The wall system of the granary consists of two parts: the enclosing surfaces and the reinforcement members(Fig.5.22). The enclosing surfaces are assembled of a series of vertical wooden planks, made from Schima wood. And reinforcing members are thin wooden sticks through the pillars.

The changes in the dimension of hardwood during the shrinkage process generally are less than softwood. However, gaps still will occur between planks in the walls of these granaries in years after the granary completed. Local carpenters used a simple way to solve this sealing problem: nailing long narrow bamboo pieces inside the walls to cover the gaps between these planks. Iron nails are used to fix these bamboo pieces with wooden planks. As iron nails were not in use in this village prior to the 1970s, there must have been a different method of nailing before or a different method of sealing at all.

Actually, bamboo mat used to be the major material for enclosing local Pulang granaries in the past (街顺宝, 2009,p53). It can still be found in some existing granaries, shown in Fig 5.23.Locals used non-woven bamboo mats to enclose the granaries. Bamboo tubes were cracked and break flat. Bamboo mats made in this way are thicker and stronger than bamboo mats woven from prepared bamboo sheets. Yet even unfold bamboo mat are still weaker than the wooden planks. Thus outer reinforcement sticks are indispensable when using such kind of bamboo mats. Locals sometimes plastered these bamboo mats with mud , in order to seal the granaries with such bamboo mats

In this particular case, three layers of reinforcement sticks districted over the wall. The main function of these sticks is the provision of resistance against the outward push of the stored rice. All weight of the rice heap pushes against the walls. Necessary for bamboo walls in any way, these reinforcing horizontal sticks also provide strengthening in case of wooden planks.

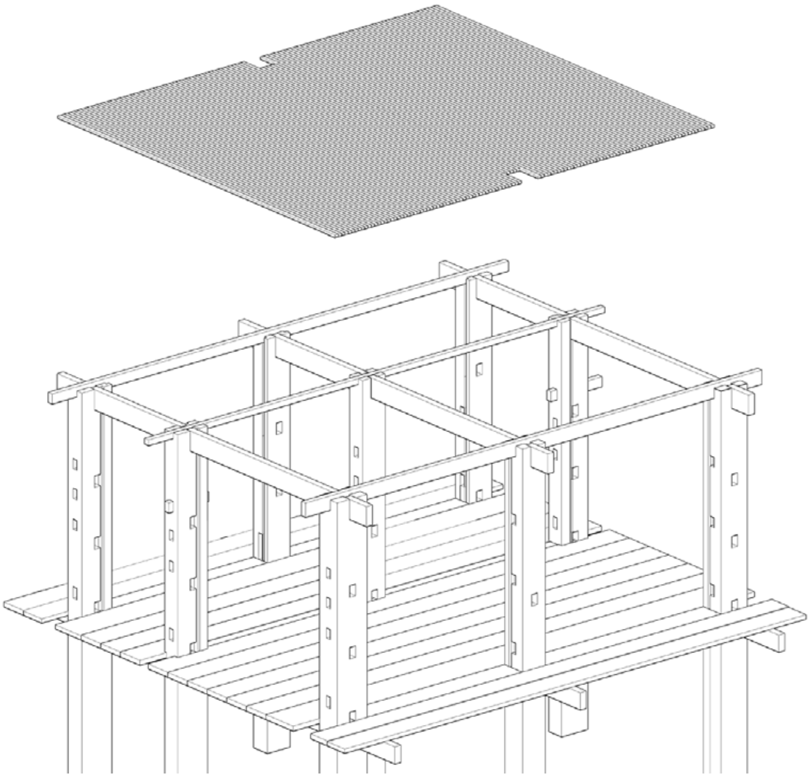


Fig.5.24

Fig.5. 24 A perpendicular plank is used for fixing the ceiling boards.

Fig.5. 25 The floor construction detail.

5.2.2.3 Ceiling and floor

The ceiling of the granary is assembled by a series of wooden planks, lying on the topmost beams in longitudinal direction. Not only offering an upper enclosure for the storerooms beneath, the ceiling also provides a plane for supporting the main roof structure above. Moreover, the ceiling also can be seen as part of the roof structure. In this case study, edges of the ceiling extend 20-30cm beyond the topmost beams. This design aims at holding cantilevered rafters, hence creating further extended eaves. Iron nails are used to fix the ceiling boards. There are two wooden planks laid perpendicular above the edges of these ceiling planks. Carpenters generally applied these two perpendicular planks to nail several ceiling boards in the intended position in order to fix ceiling boards(Fig.5.24).

The floor of the granary usually consists of two layers: an upper bamboo mat layer and a lower wooden plank layer(Fig.5.25). The bamboo mats are laid on wooden planks in a perpendicular direction, while these wooden planks are laid in longitudinal direction. This can be seen as a sealing way. All sides of the floor planks are butt jointed. Considering the wood property to adapt to ambient humidity, gaps in between the planks must occur. As time goes by a considerable amount of rice would sift between these gaps between the planks. Hence the bamboo mats were added for sealing the floor.

5.2.2.4 Roof

Most of Roofs of granaries in Zhanglang are hiped roofs, covered with roof tiles. Before the 1990s, local granaries were still covered with grass mats, which needed to be repaired regularly.

According to the measurement, the wooden roof structure is a rather independent structure put on top of the ceiling. The structure determining the roof's shape is formed by two short pillars and a ridge beam. The short pillars are strengthened by struts jointed in traditional way. That means that their top ends were mortised into the pillars while another ends were nailed to the ceiling boards. The jack rafters were also simply nailed.

5.2.3 Variant

Apart from wooden granaries, there are still some bamboo granaries in Zhanglang as well. Bamboo granaries are granaries with bamboo pillars and walls, and beams. Reinforcement members and floors of which are mostly made of wood(Fig.5.24). Compared to these wooden granaries, bamboo granaries are generally smaller. Most of bamboo granaries are four- pillar granaries.

In comparison between a bamboo granary and a wooden granary, two details can be realized: 1) pillars and beams of the bamboo granary follow nearly the same unique way of connection as we have detected in the wooden granary. 2) Bamboo granaries mostly rely on earth to hold their posts, they reflect a more primitive building technology.

All current constructions existing in Zhanglang were built according to a new building technology after the 1980s. Only literature records can still provide some characteristics about former buildings: posts are buried in the ground, bamboo mats were used as walls. Since these features appear in the remaining bamboo granaries, we can suppose that the bamboo granary actually maintains some important primitive features of former granaries.

5.2.4 The changing building technology

In the 1980s, the traditional building technology of Zhanglang village had experienced a big change due to the introduction of a series of new building tools and building methods, which are thought to be more advanced. The building craft of the granary had also been influenced by this trend.

In a comparison between a typical wooden granary done in the

1980s and literature records about the former granaries built before the 1980s, we realize that changes mostly occurred in the following aspects:

i. **Roof.** The formerly thatched roofs of granaries were gradually replaced by tile roofs in the 1980s. Accompanying with the disappearance of fallow fields in the 1980s, one of the main sources of congo grass had gone lost. At the same period, the construction of the roads made transportation of roof tiles into villages become easier. Meanwhile, the tile roof is accepted as superior to the thatched roof in terms of rain resistance and durability.

ii. **Wall.** More and more families built granaries with wooden planks after the 1980s, while bamboo walls were more popular before. This could relate to the introduction of the saw in the 1970s. (街 顺 宝 , 2009, p42). Without a doubt, the wooden planks walls are more durable and stronger than the bamboo walls.

iii. **Pillar.** The posts of former granaries were buried in the ground, while the pillars of current granaries mostly stand on stone bases(街顺宝 , 2009,p113) .The application of pillars standing on foundation stones aims at preventing the decay of roots of pillars in a short time.

Consequently, these changes improve the durability of local granaries in different ways, and free local farmers from the onerous regular renovation works. However, the former building knowledge had not yet been totally forgotten. There are still some characteristics of former granaries that can be observed in existing granaries.

One of these preserved characteristics are the reinforcing sticks. Reinforcing members are necessary components for granaries with bamboo walls. However, many wooden granaries were still built with reinforcing sticks, even when bamboo walls were replaced by wooden planks in these construction projects.

One of the other preserved characteristics is the weak connection between pillars and beams. This is an unusual feature for a wooden granary with pillars standing on stone foundations. In the Pulang example shown in this section, wedges are widely added to strengthen these joints. This technology is much simpler but also weaker. Only when we suppose this feature is a leftover technology of the former granary, we have a simple explanation. Posts, which were buried in the ground, can collect a considerable amount of side thrust. As they are fixed in the ground, they can be seen as vertical cantilevered elements. Thus local carpenters did not need to consider how jointed beams and pillars dealt with the side thrust. While, in currently existing granaries standing on stone foundations reinforcing sticks help to strengthen the whole structure, especially against the side thrust.

5.3. Wa village: Wending

Fig.5. 26 Indoor bamboo baskets for storing rice。(source:韩军学 ,2007, p. 87)

In comparison to Pulang village, Wa villages generally are located in more remote mountainous areas along the border between China and Myanmar.

In many Wa villages, three methods were generally used for storing cereals in a farm family in the past (Fig.5.26):

i. Big bamboo stem containers: Locals cut three to four meters long Dragon bamboo stems and turned them into rice containers. These containers used to be stored on horizontal beams of roof structures. To make such a container, Wa people generally cut out all intra-nodes of the select section besides one end, and would close it with mud on the open end after having filled the bamboo pole with rice. This method is thought to be the most ancient rice storing way in Wa settlements（韩军学，2007,p97).

ii. Bamboo baskets: This kind of basket is generally 1 meter high and has a diameter of 1 meter. This basket was mostly located indoor, if outdoors, then always close to the doors.

iii. Wooden granaries: Wooden granaries of Wa families are generally not so big, consisting of two to three bays. The wooden granary was considered to be built only by rich families in an earlier record on Wa region completed in 1958（张捍平，2013, p99). However, according to the field survey in Wen'ding, it has become the most common rice storing way nowadays. This may be related again to the promotion of using saws in Wa regions.

In the past, many Wa families used all these three types of storing at the same time. In this case, these three different types of containers mostly served different functions: the big bamboo stems were used for storing seeds for the next season. The bamboo baskets kept the daily consumed rice, and the wooden granaries were used for storing rice that was kept as emergency food(韩军学，2007,p97).

5.3.1 Village, dwellings and granaries

Wending is a big Wa village located in Changyuan, the West on border of Yunnan. It is also located at the periphery of Awa mountain （阿佤山）area. There are around 100 families living in this village, which can be regarded as a comparatively big village among Wa area.

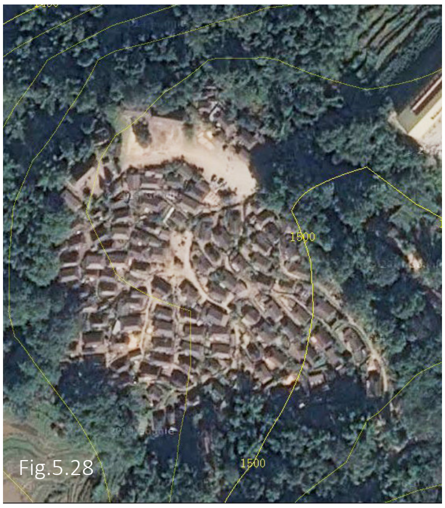


Fig.5. 27 The Wa village: Wending

Fig.5. 28 The satellite map of Wending, Changyuan, Yunnan.

Similar to Pulang villages, Wa villages are also mostly located in high regions of mountainous areas. In Wa people's tradition establishing a village in a higher place is good for health. In their mind they thus avoid the humid environment in valley regions.

5.3.1.1 Layout of Wending village

Wending village lies on top of a hill in mountainous area (Fig.5.27,28). The whole settlement is built on the west slope, facing the lower valley area. The valley area is reclaimed for cultivating fields. Similar to the Pulang village Zhanglang, this village is also enclosed by a circle of trees. These trees maintain the groundwater resource of the village, and additionally, they provide a defensive barrier for the village. Compared to Pulang villages, Wa villages generally paid more attention to defense due to the ancient 'Headhunting' culture. In Wending locals even dug a moat in the forest surrounding the village to enhance defense measures. Additionally, they plant prickly bushes and bamboo bushes along the moat, to strengthen the defense situation of the village. Some villages would even build bamboo fences around their settlements (王翠兰, 1993,p97). There are three wooden village gates along the border of the village. People must pass these gates to enter the village. They are landmarks and checkpoints as well. In the past, when strangers wanted to enter the village, they had to accept being checked at these gates by local guards.

Close to the border of the village, there are a series of holy places in the villages including the ghost forest and a wooden drum house. The most important sacrificial ceremonies, such as sowing festival and new rice festival, would be carried out annually in these places at a specific date. However locals would avoid entering these place in daily life.

Inside the village, dwellings were arranged densely around the central square, that is seen as the “village’s heart (寨 心)”. The distance between neighboring dwellings is generally short, mostly around 5 meters. With such short interspace, fires spread easily among the whole village within a short time. Heavy losses are the consequence. In the past, locals usually prepared long bamboo poles with hooks for removing burning grass from the roof, aiming at stopping the fire from spreading. There are also two pools in the village providing water for extinguishing a fire. However, the effect of these methods was fairly limited. According to narratives of locals, the whole village had been nearly burnt down two times, in the 1960s and 1980s respectively (张捍平 , 2013,p19). After the earthquake in 1988, many locals tried to apply new material for building their new dwellings, such as bricks and asbestos roof coating. These materials are supposed to be more fireproof and more stable. However, due to the conservation program starting in 2004, locals are persuaded to use thatched roofs and wooden structures again today.

5.3.1.2 Traditional Wa dwelling

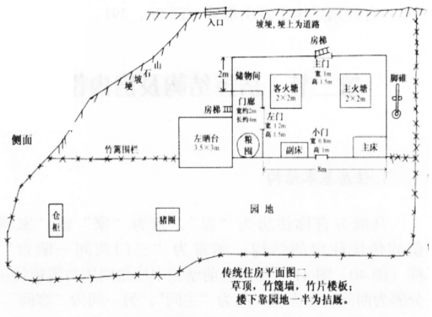


Fig.5. 29 A site plan of a Wa dwelling in the past. (source: 韩军学 ,2007, p. 92)

The majority of dwellings in Wen’ding are one-family houses, intended to house a couple and their children. When the children are grown up and got married, they need to leave their parent’s house and find a new place to build their own house. Only one child (a son if available) of the parents inherit the parent’s house, while this detail’s responsibility is to take care of his or her parents until they pass away. The typical Wa family size is around 4-5 persons nowadays.

Generally a Wa dwelling is located in a flat yard enclosed by a low stone wall or a bamboo fence. (Fig.5.30) Prickly plants would be also planted around the garden, as a further defensive measure. The area of the yard is generally not big in Wen’ding. Locals mostly built a series of outbuildings in their yards, including drying platform, pigsty, chicken house, firewood shed. The drying platforms are mostly built with bamboo. Rice used to be dried at this place in the old times. Many families built more than one drying platform in their yard, depending on the amount of their hartvest. Some locals also put their granaries in their yards.

The old local Wa buildings are characterized by posts, thatched roofs and elevated floors. Traditionally, the number of posts implies the status of the family. In other word, the amount of posts determined the size of a house. The scale of a house demonstrates the owner’s rights and status. There were two common building types mostly

Fig.30

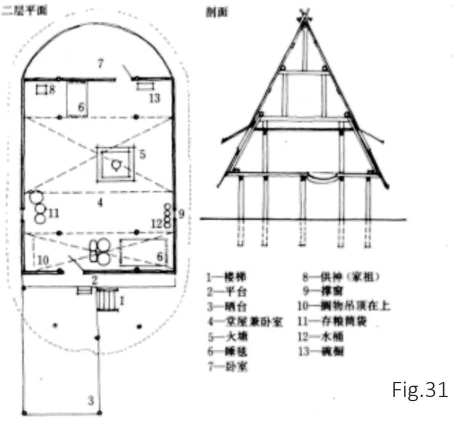


Fig.31

built in the past: ’four- pillar style(四大柱)’ and ‘eight-pillar style(八大 柱)’. Ordinary families usually built ’four- pillar style’ dwellings, while only headman and *Moba*[8] (魔 巴) can build ‘eight-pillar style’ dwellings. The building materials used in these two different types of buildings was also different in the past. Wooden planks can be partly used for closing walls in the construction of the ‘eight-pillar style’ dwelling (徐志远 , 2009, P45).

Fig.5. 30 Plan and section of a typical four-pillar style dwelling, Changyuan. (source: 王翠兰 ,1993,p109)

Fig.5. 31 A open-fireplace area in a traditional dwelling.

The image (Fig.5.30) shows a typical ’four- pillar style’ dwelling in the Wa village Changyuan. The ground floor of the dwelling is a semi-open space without enclosing wall, while the main living floor is a long space covered under the roof. Inside, the four main pillars define the core space of the house, where the main fireplace is located. The fireplace is one of the most important places in a Wa house. The eldest family members generally care for it. He or she sits all day long next to the fireplace to entertain the fire (Fig.31). The fire provides heat not only for cooking but also for warming up the whole house. The heat from the fireplace is an effective method to keep indoor space dry under the local humid environment. Usually there is hanging a bamboo basket above the fire place. Pieces of meat and some other foods are put there for smoking and drying. In some families they lay big bamboos tubes filled with rice on the lower beams of the roof structure. Hence, the heat from the fireplace offers a good condition for storing rice in this way. In some cases bamboo baskets were used for storing rice indoor space.For the convenient access,farmers mostly located these bamboo baskets in the place next to the door.

8. *Moba*（魔巴 : Priests in Wa villages.

5.3.1.3 Location and social factors of granaries in the village

Unlike with the Pulang village Zhanglang, this village’s granaries were dispersed at various locations in the village, without following any regulation. Some granaries are located along the paths into the village, while some are located at high places in the village (Fig.5.32). There are also some granaries built close to the dwellings to whom

Fig.5. 32 Granaries located next to the main road of the village. They are protected by a short wall.

Fig.5. 33 One of the oldest granaries of Wending. It is located in a flat place enclosed by a short wall and shrubs. It was selected to be the study case in this section.

they belong. According to locals, after the two big fire disasters, some families moved their granaries away from their houses. However, we have to be careful with explanations or justifications. As I mentioned in the former part, quitting traditional habit caused a social change that promoted a change of building habit as well. This could be a plausible argument as well.

In the past, families would mostly locate their wooden granary inside their yards (张捍平 , 2013,p19). This situation was documented in some early Wa houses 'measurements in the 1960s (韩军学 , 2007, p92). These early records also suggest that some families would put wooden granaries without directly roofs under the eaves of main buildings. In a word, it was quite common that a Wa granary was located in a very close place to the owners' dwelling in the past. The situation gradually changed since the 1960s. According to my investigation, in Wen'ding, more and more families decided to build their granaries at places far away from their dwellings.

We need to put the question: **what consideration promoted a Wa family to build their wooden granary close to their house in the past, and why did this habit change afterwards?**

The ancient 'headhunting' tradition can be one explanation. Due to 'headhunting' activities, mutual vendettas between villages used to be common in the Wa region. 'Headhunting' young men of a village attacked another village to gain someone's head, and this behavior was usually accompanied by robbery and arson. This usually led to a series of bloody reprisals (徐志远, 2009,p53). Some cases of robbery against villages show that groups of granaries located on the borders of the village were easier to become the target of robbery and arson, as the case of Denceng. If the groups of granaries were burnt down, famine among the whole village would be hard to avoid. On the contrary, locating granaries close to their owner's dwellings means that dispersing these granaries in the village. Though this way, the risk that all granaries are burnt down at the same time decreases. For sure the locals know that Fire occurred regularly due to open fireplaces in the dwelling houses can burn down the granaries locating close to the dwellings. But compared to the loss of groups of granaries, the loss of one or two granaries is negligible. Considering such a condition, I assume that Wa people thus decided to build their granaries next to their house, protected by fences or walls.

Soon after the late 1950s when the new central government successfully persuaded all Wa villages to stop the 'headhunting' tradition (徐 志 远, 2009,p54), they began to erect their granaries at places far away from their dwellings. In nowadays Wen'ding, we can observe exactly that many granaries are located far away from the dwellings. This can be a piece of evidence supporting my assumption.

All these granaries comprise a general characteristic. They are mostly enclosed by a barrier. This can be thought to be a remaining traditional idea that a personal granary should be well protected even in the village. Locals usually would use bamboo fences, low stone walls, or prickly shrubs to build a barrier around the granary, as is shown in the image.

5.3.1.4 Cultural meaning of the Wa granary

Under the local 'rice spirit'(谷魂) worship, granaries are traditionally thought to be the home of the 'Rice spirit', residing in the rice heap. In another word, a granary can be regarded as a shrine of rice in Wa concept. There are many rituals and taboos related to the granary in Wa villages, including the 'New rice festival'. Most of them are for praying for a good harvest.

Consequently, due to its cultural status, a Wa granary needs to be carefully built at a high standard. It is not surprising that locals used only wooden planks to enclose their granaries. As they thought wooden planks can only be used in high-status buildings in the past. Additionally, local carpenters sometime would carve a symbol of Holy Bullhead on some granaries as a decoration, to indicate the sacredness of the granary.

5.3.2 Granary

The selected object is one of the oldest granaries in the village(Fig.5.33). The owner of which believes it was built in the early twentieth century. The processing traces on timber components of the granary suggest that most surfaces of it had been shaped or smoothed carefully by an axe or adze. It can be confirmed that it had been built before the 1980s, when saw became a common carpentry tool in the village.

Enclosed by a low wall and a bamboo fence, this granary is located in the middle of a yard. The storage capacity of the granary reaches 3000 kg. It is mainly used for storing rice. Locals also stored other cereals such as millet together with rice in it in the past.

This selected granary shows a nearly square plan, which is divided into two rooms(Fig.5.34). The whole granary is built above six stone

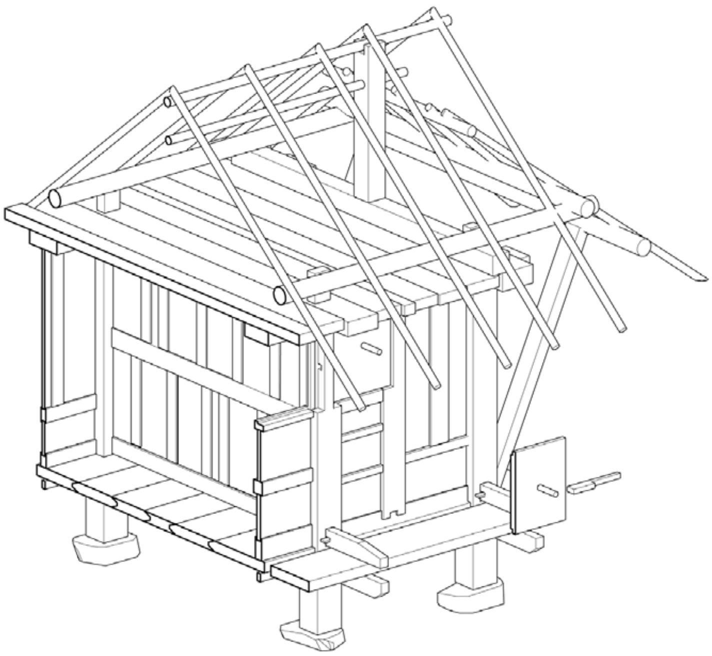


Fig.5. 34 The 3D-model of the selected granary

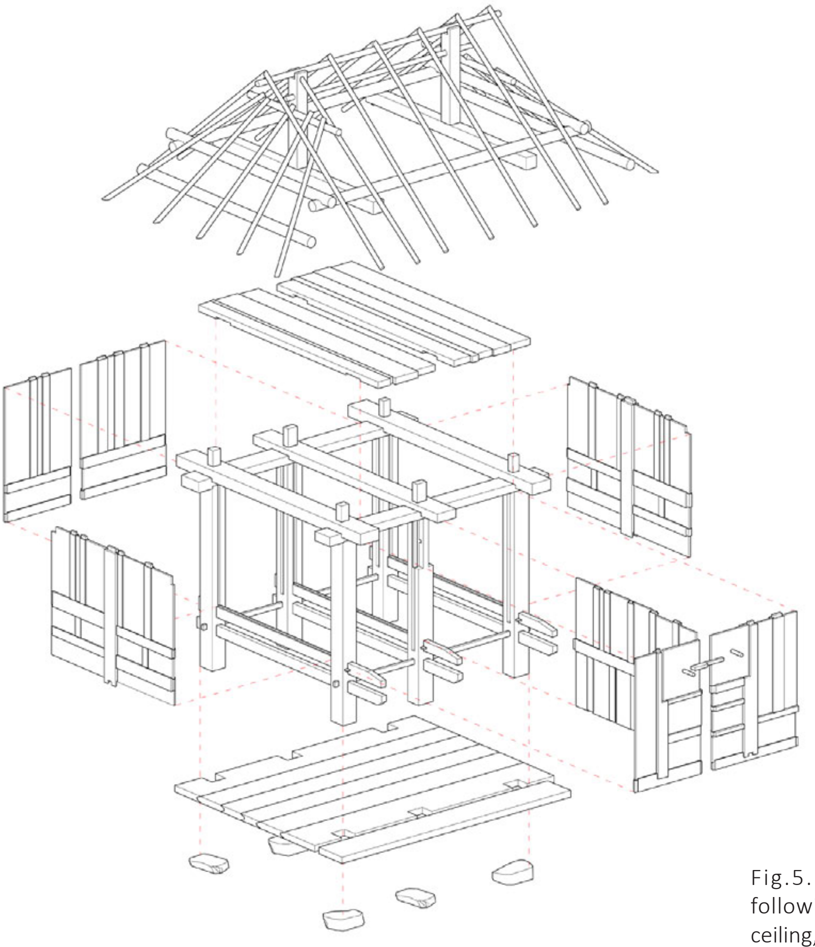


Fig.5. 35 The granary consists of these following parts: the main framework, walls, ceiling, floor, roof structure, stone bases.

bases left in their natural shapes. In order to keep the structure stable, the roots of the pillars are shaped irregularly to adapt to the stone bases. The floor of the granary is elevated around 80 cm from the ground, aiming at creating air ventilation beneath the granary. However, this floor height raises a problem for using the granary. The openings of local granaries are too small to enter them upright. The sills of these openings are usually mounted around 1.1 meters off the elevated floor. In order to make it is easier for people to store rice into the granary, carpenters created a narrow platform extending from the granary that acts as a step.

Measurement work shows that this granary consists of these following parts: main framework, walls, ceiling, floor, roof structure, stone bases (Fig.5.35).

5.3.2.1 Framework

The main framework of the granary is assembled from six pillars and two layers of tie beams (Fig.5.36). The transversal column distance is nearly twice the distance of the columns in longitudinal direction. This is good for supporting the floor planks laid longitudinally.

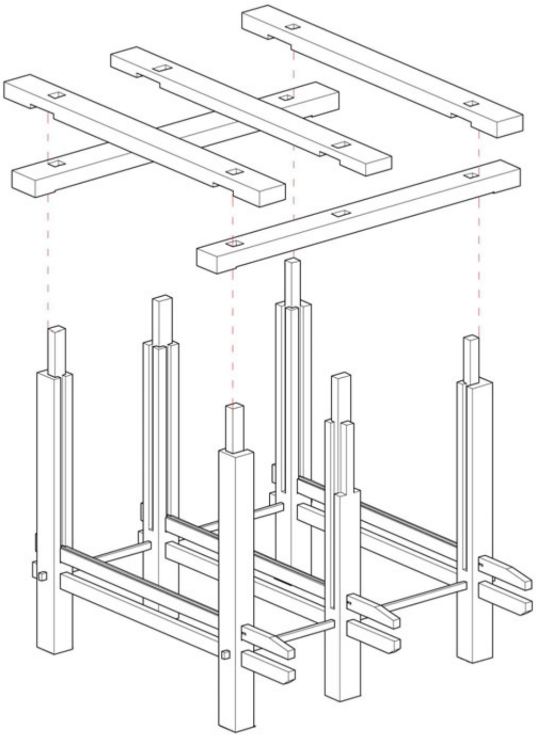


Fig.5. 36 The main framework of this granary.

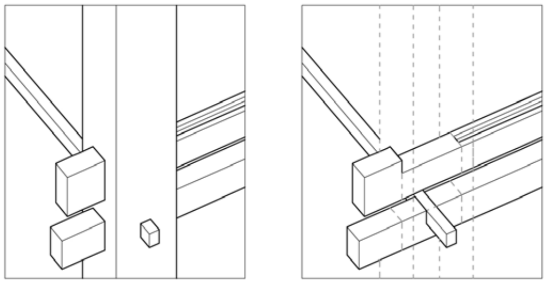


Fig.5. 37 The joints of the two lower tie-beams in the rear side of the granary

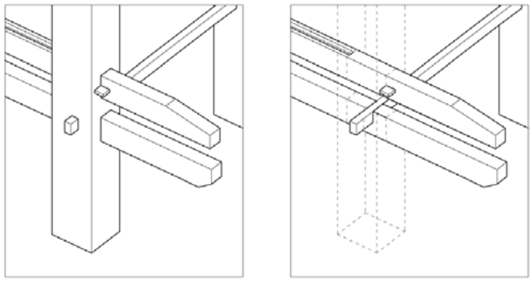


Fig.5. 38 The joints of the two lower tie-beams in the front side of the granary

Measurement of the granary shows an interesting detail .The spacing of the two bays of the granary is uneven. This can be related to the absence of rule in their former building construction process.

The two lower layers of transverse beams connect with the pillars in different ways (Fig.5.37,38). The lowest transverse beams carry all load of stored rice and the upper transverse beams carry the walls. The floor planks were fixed between these two lower tie beams. In these two layers of transverse beams, the upper ones were significantly broader before its processing. The exception is the end protruding beyond the pillars. Keyed joints are used in these ends for preventing the outward movements of the pillars. The other ends of transverse beams halted by pillars are thicker. Wedges and thicker ends contribute to secure beams in the intended distance, thus defining the distance of the two pillars belonging to each other. Their specific execution secured the pillar pair against being pushed against by the thrust of the stored rice. The lowest tie beams are notched inside pillars on its upper sides to house two astonishingly thin longitudinal beams. These two thin longitudinal beams also acts as wedges.

The mounting of the upper horizontal frame is comparatively simple. All pillars' top ends are reduced to tenons with four shoulders. In the first step, the pillars are connected by two beams longitudinally. Each beam is pierced three times to thread the pillars in their intended distances. In a second step, three beams are laid perpendicularly above the longitudinal beams. In order to give the whole construction stability, the upper beams are recessed at half height to be cogged with the two longitudinal beams. Additionally, they have cut holes like the two lower beams to receive the pillars' tenons. Consequently, we have not yet mentioned another important structural feature. The given description of the composition of the structural frame explains the pillars' stable position. But there could be no provision to keep right angle unless the strengthened frame would be secured otherwise. Grooves in all relevant structural components house closing boards that cause the stability of the angle.

5.3.2.2 Wall structure

Due to the difficulty of logging and converting wooden planks in the past, wooden planks were rarely used in former ordinary Wa houses. Traditionally only granaries and houses of high-status families applied wooden planks as wall structure. As mentioned before, the wooden wall was considered to serve as a representation of high-status. Seen from a structural point of view, the wooden wall is obviously stronger than the woven bamboo wall.

Wooden walls of Wa granaries also face the sealing problem, which is a main problem in granary construction. We must take into account that the carpenters' skill was restricted as coarse tools limited their ambitions. Under such circumstances local carpenters developed a time-consuming paneling method to solve this problem(Fig.5.39). Shown in the picture a side wall of the granary consists of two types of elements: in-filled wooden panels and wooden mullions with grooves. The edges of these panels were shaped thinner, thus they can be easier installed in the frames. Similar wall paneling method is also found in a granary model of Han dynasty, more detail can be found in section 2.4.2.2.

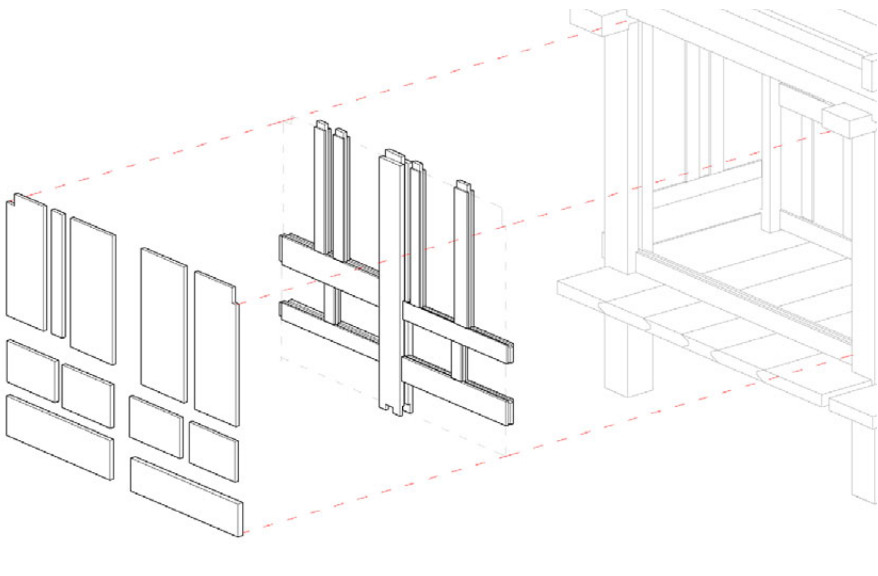


Fig.5. 39 Wall construction of the granary

Considering the workflow the walls had to be inserted before the upper horizontal frame was installed. The construction follows a certain order: the vertical central mullion should be installed into the grooves of the main frame firstly, then panels and the sub-mullions were installed into the frame in sequence. For installing the last vertical panels, the upper transversal beams should be lifted up a short distance to make space for this action. And these upper beams needs to be fastened again after whole walls were done.

The construction of the wall system of the granary shows the local Wa carpenter's knowledge. The application of this paneling method is based on experience in handling the wood material. Trees grow pyramidally. When trunks are cut lengthwise, their section appears tapered. Long boards with parallel edges cause a lot of waste. The amount of waste can be reduced, if one board can be cut into several shorter boards. Shown in the photo, the panels applied in this ancient granary are generally small, and are of quite different sizes. Locals seem to have put quite some energy to make best and efficient use of all parts of the tree. This can be seen as an efficient way to save timber material, which was extremely precious since cutting trees and transporting timbers were relatively difficult tasks in local Wa villages in the past.

Additionally, applying smaller pieces of wooden planks in a paneled wall provides another advantage. The wall is assembled of panels and mullions with tongue and groove joints. The overlapping of panels that are larger than their corresponding frames is considered in grooves that are still larger than the panels plus tongues. This

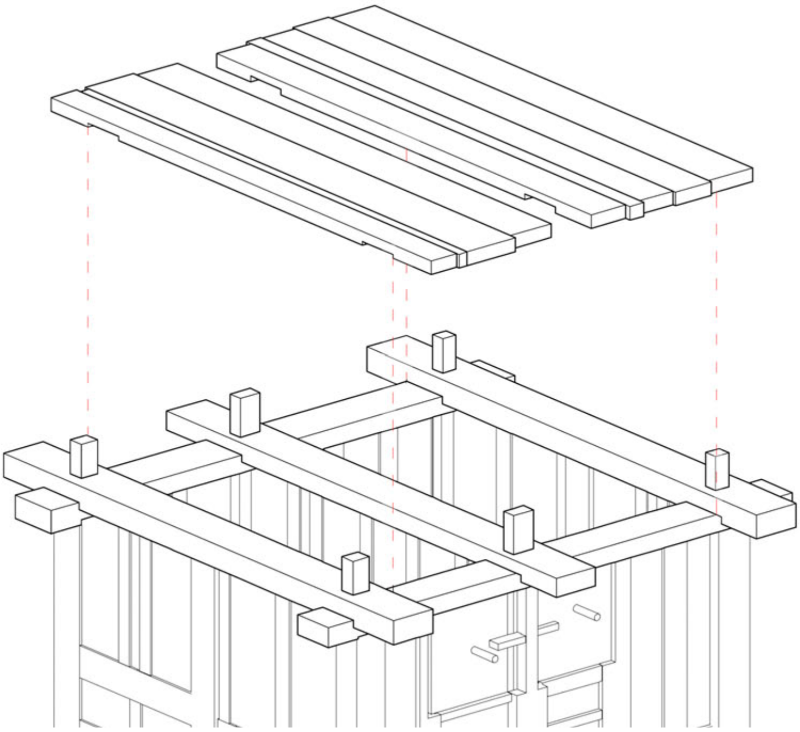


Fig.5. 41 Ceiling construction of the granary

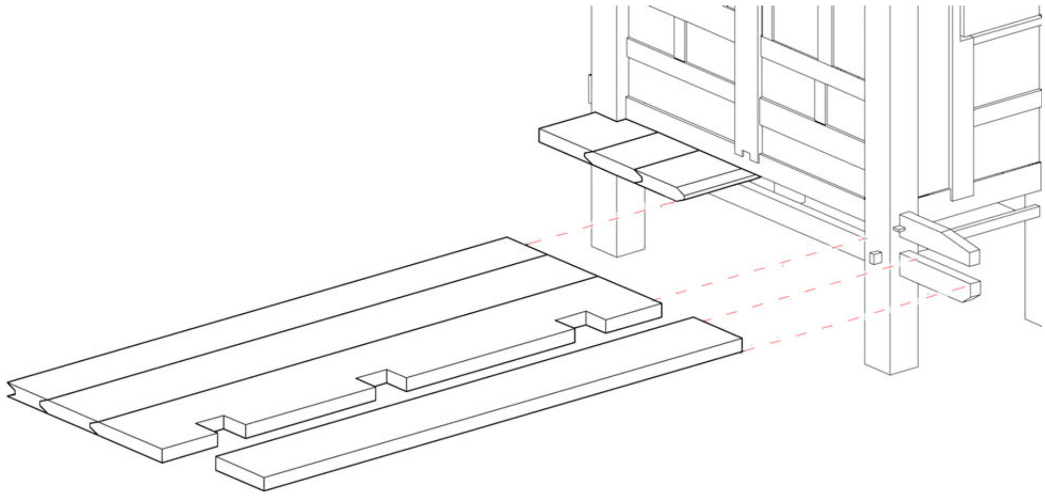


Fig.5. 42 Floor construction of the granary

measure allows shrinkage as well as growth depending on ambient humidity. Thus the walls themselves stay sealed under all conditions.

5.3.2.3 Ceiling and floor

One significant feature of this old granary is the thickness of ceiling and floor. This granary owns a 5-cm thick ceiling and 8-cm thick floor, much thicker than common granaries. The reason is the local primitive method of timber process. In addition, the ceiling and the floor act as the structural reinforcement members of the whole structure.

The ceiling is assembled by a series of 5-cm thick planks, laid in the transverse direction (Fig.5.41). Carpenters incised broad notches close to the out ends of each ceiling planks. In this way, the ceiling planks are cogged to the top longitudinal beam thus fastening the mainframe in transverse direction.

The floor planks with 8cm are still thicker than the ceiling planks(Fig.5.42). This relates to the heavy load of storing rice. They are laid along longitudinal direction. Carpenters carefully shaped the edges of these planks into kind of tongue and groove joints, with tapered edge shape. This can also be related to their rough carpentry tools. Both ends of the floor planks exceed around 45cm off the exterior walls. Two boards had to be adapted in order to close the floor height. Recesses omitted space for the pillars. This measure added to fasten the mainframe in longitudinal direction. Accordingly, the mainframe is strengthened by ceiling and floor in both two directions.

5.3.2.4 Roof

The roof of the granary is an independent rough structure standing above the ceiling, covered with asbestos roof coating and grass mats. According to traditional building preservation requirements of the village, all roofs should be covered with grass. However, some farmers add a layer of asbestos roof beneath the thatched roofing in recent years aiming at enhancing the rain resistance and reducing the amount of needed grass. Since the layer of the thatched roofing only acts as a decoration in such a tricky construction, the roofing layer became much thinner than before.

The main structure of the roof consists of two parts: the wooden roof frame and bamboo rafters. Traditionally all bamboo rafters were bound to the wooden roof frame with knots. Nowadays iron nails are widely used to replace those knots. In the past regular renovation should be executed every five to ten years. The wooden frame needed to be taken apart and then rebuilt regularly. Meanwhile only bamboo rafters are replaced in the repeated renovation process. Rafters tended to rot easily as they were placed directly under the thatched roof in former times. On the other hand, the regularly executed exchange process reveals why rafters of the Wa granaries are mostly made of bamboo. Compared to wood, bamboo can be obtained effortlessly.

5.3.2.5 Door

Each door leaf of the granary is made of one whole piece of wood. A wooden stick is driven into the center of the leaf, acting as a handle. The door leaves are fixed with the fame by a horizontal tapered stick. To open the door, one needs to use a wooden mallet to kick out this stick. The big noise produces when the door is opened was used as a security measure to protect the granary in the past. Similar designs are also applied in some Yao and Dong granaries.

5.3.2.6 Summary

Several significant features of the Wa granary are closely related to the simple carpentry tools of the Wa people. Their traditional carpentry tools consisted mainly of the long-handled axe with small knife, adze and chisel. Due to the lack of more efficient tools in the past, the size of raw available timber materials was quite limited. This largely promoted the development of panelled walls in granaries under the sealing requirement. Lacking saws locals were forced to spend a lot of time with cutting and trimming timber for building. Split boards as they are used for the panelling are necessarily thicker than sawn boards can be. This does not need to be seen as disadvantage. Thicker planks ensure the strength generally. These mounted in the floor and ceiling strengthen the structure against side thrust.

The regularly repeated renovation of the Wa people's granaries resulted in less conspicuous but relevant characteristics. Many reused construction members can be found in granaries built before 1980s. Mostly they comprise members of minor structural importance like mullions. I assume that some joints are designed to facilitate so often required reconstruction or renovation processes, such as the moveable topmost tie beams.

5.3.3 Variants and changes

The saw was introduced in this village in the 1970s, the machine saw in the 1980s. Since then, logging and tree conversion have become a much less demanding work. Many of the existing granaries of this village were built after the 1980s.Might will be that the introduction of machine driven saws supported this building boom.

Fig.5. 43 A newly built granary

The promotion of the saw also led to some changes in the local granary construction technology, especially the wall construction. We can show this in a granary built in the 1980s (Fig.5.43). Although it was also built with panelled walls, it is easy to find some differences with walls of the ancient granary mentioned in the last section. Firstly, the panels and the mullions applied to the younger wall system in similar sizes. Thus the arrangement of the mullions of a wall becomes more regular. Since the application of the saw reduced the difficulty of preparing timber, carpenters did not need to use as much effort to use irregularly sized planks as before. Secondly, the thickness of the mullions became less than before, as carpenters can produce thinner elements than before. The application of thinner elements can thereby save timber in a way. However, advantages can be accompanied by disadvantages. The thin mullions are thought to be not strong enough to resist the side thrust of the stored rice. Hence some carpenters added some horizontal reinforcing members outside the walls, which act as a reinforcement method. Some locals also reduced the dimension of lower beams of their granaries. This sometimes causes the outward deformation of the beams due to the large side thrust. In order to prevent this unfavorable situation, carpenters added wooden nails vertically along the edges of the beams for impeding their outward pressure (Fig.5.44).

Fig.5. 44 Wooden nails were added vertically along the edges of the beams for impeding their outward pressure

Wooden Granarie in Rgyal-rong[1] region,Sichuan

6.1 Background

6.1.1 Environmental and Social factors

Sha'er region is a part of Cha Bao valley located in Barkam, Northwest Sichuan (Fig.6.1) .This area is one of the most remote mountainous regions in Sichuan. Only one narrow road connects this region to the outside world when we visited it in 2016. In history, it used to be ruled by Rgyal-rong Tusi[2] before the 1950s. It has its own unique dialect: Chabao language.

The region is in a border region between alpine steppe and mountain region, at an altitude between 2750-4000 meters. The climate of this region owns some typical plateau features: strong sunshine and abundant wind resource. Meanwhile, due to the local Chabao River and its valley topography, this region is moister than the surrounding plateau regions. The annual precipitation of this region reaches 862mm, much higher than other surrounding regions (四川省马尔康县地方志编纂委员 ,1995, p.59). This leds to abundant forest growth in the area in the past. Most of the local mountain slopes were covered by the virgin forest before 1957.

From the cultural aspect, Sha'er region is considered as a border region. It used to be located between Tibetan agricultural region of Sichuan, the so-called Rgyalrong region and Sichuan Tibetan pastoral region, the so-called Amdo region in the past. Through time it became a kind of junction of two different cultures. Tibetans of Sha'er mainly engage in agriculture and animal husbandry at the same time. On the other hand, the boundary location also means that this area was far away from the political center, thus it is partly out of governmental control. Meanwhile, there was an important traffic road across this region from the agricultural region to the Tibetan pastoral region before the 1950s. Bandits were rampant in this area at that period (阿坝藏族羌族自治州地方志编纂委员会 1994, p.2174). Thus, defense became an important consideration for local dwellings and village layout in the past.

6.1.2 Cultivation and harvest of highland barley in Rgyal-rong region

1. Rgyal-rong people (嘉 绒) , also refers to rGyalrong people.They live in the north-west corner of Sìchuān. They used to be defined as an independent ethnic group. After the 1950s, they were defined as a branch of Tibetan people. They have their own language.

2 Tusi (土 司) often translated "headmen" or "chieftains", were hereditary tribal leaders recognized as imperial officials by the Yuan, Ming, and Qing-era Chinese governments. They ruled certain restricted areas in minority region in South east China before the 1950s, belonging themselves to this minority people.

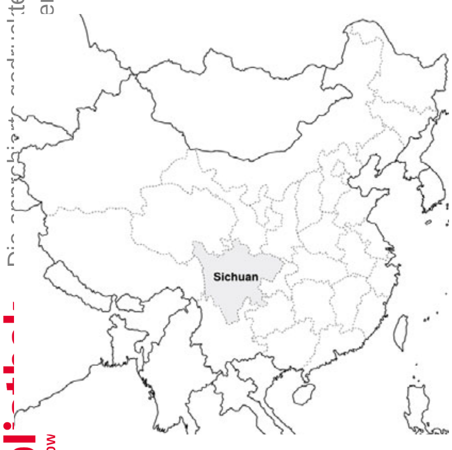


Fig.6. 1 Location of Sichuan province in China.

In the plateau region of Sichuan Province, highland barley (*Hordeum vulgare Linn. var. nudum Hook.f.,* Chinese:青稞)is the main traditional staple for the local Tibetan people. Highland barley could grow well in plateau with the altitude over 3000 meters, while most of other crops cannot.

The highland barley is a variant of barley. The outer hull of this species is loosely attached to the kernel. It generally falls off during harvesting. This helps to reduce the hulling process during the crop harvesting progress.

The harvest period of highland barley in the Sichuan plateau region is from mid-September to the end of September. The yield of the highland barley is much less, compared to rice. Generally the yield of highland barley in valley areas at lower altitude such as 2700 meters would be around 100-150 kg per *Mu*, according to the interviews with locals. While the yield of highland barley is higher on the hillside fields with a higher altitude over 3000 meters, which could reach 150-200kg per *Mu*.

The harvest process of highland barley in Rgyal-rong region can be structured into the following steps (Fig.6.2):

i. Reaping and transportation: Tibetan farmers traditionally used short handle sickles for harvesting highland barley, and tied the stalks into bundles afterwards. Then they used ropes to carry several bundles of highland barley on their backs to the drying place. Generally this kind of transportation work was women's duty in the past.

ii. Drying: The freshly harvested highland barley needs to be hanged on drying racks for 10 to 20 days. In drier areas, drying racks are mostly erected independently next to roads or villages. However, in more humid areas, such as the Sha'er region, the drying process lasts much longer. In a place with poor public order, longer drying duration in free standing drying racks along roads increased the risk of loss. Thus many Tibetan farm families of Sha'er region put drying racks on the top of their own dwellings to avoid such risks.

iii. Threshing: When highland barley is dry, the threshing process

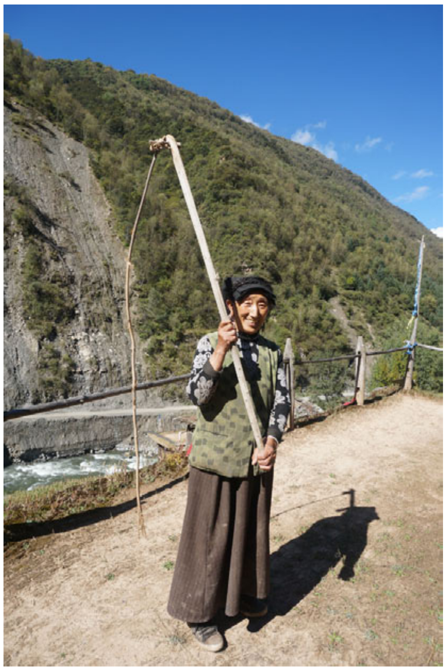


Fig.6. 3 The wooden flail was used for threshing highland barley in the past.

Fig.6. 2 The harvest process of highland barley in Rgyal-rong region.

Fig.6. 4 Highland barley

is carried out in a flat place. In the Sha'er area, this process usually happens on top of tower dwellings. First, ears of highland barley are separated from the stalk, placed in the center of this flat place. Two or more farmers then thresh them with long wooden flails (Fig.6.03). This process usually makes cereals splash away. Farmers thus usually use wooden planks to enclose the threshing area, in order to reduce the loss of cereals during this process. Nowadays, electric thresher machines are widely applied for threshing in this region instead of wooden flails, then the threshing areas are usually moved to the ground floor.

iv. Winnowing: Winnowing traditionaly relies on natural wind in this region. Farmers firstly collect the mixture of grain and chaff into a kind of round flat baskets, put a bigger flat basket on the floor, and throw the mixture into the air to let the wind blow away the lighter chaff. Then the clean grain would be left in the bigger flat basket. This process usually happens on the top terrace of tower dwellings in Sha'er region, where the wind is strong. Many farmers also use wooden winnowing machines nowadys.

Then clean cereals can be stored in storerooms (Fig.6.4). Highland barley can still be eaten even after having been stored for many years. Locals usually use long-term stored grain for brewing wine. They believe the quality of wine made from long-term stored highland barley can be better.

Local Tibetans usually eat highland barley in powder form. They bake an amount of highland barley in a large pan before carrying it to the water mill. After grounded into powder, local calls it "*Zan Ba*"(糌粑). Zan Ba is good with milk tea, or hot water. It is the main

Fig.6. 5 Tower dwellings, De'er Ba, Dazang, Sichuan.

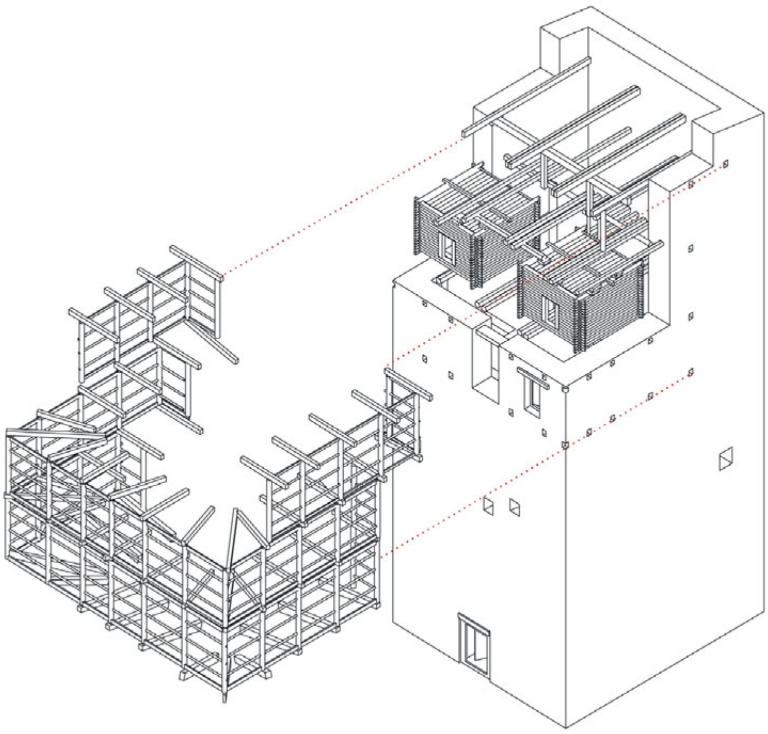


Fig.6. 6 The structure of a tower dwelling is usually a stone-wood mixed structure.

staple food for local Tibetan people.

6.1.3 Building technology of Tibetan people in Sha'er region.

The traditional dwellings of Sha'er region are a unique type of buildings called tower dwellings（碉　楼）. These buildings mostly are three to six storeys high, with very narrow and compact floor plans(Fig. 6.5) . Very few windows are cut through the walls. This makes them look very enclosed and defensive. The structure of such a dwelling is usually a stone-wood mixed structure: the main body is a masonry structure, while some building components of upper floors are made of wood, such as cantilevered verandas, granaries, and some indoor supporting members(Fig. 6.6).

6.1.3.1 Masonry building technology of local buildings

Rgyalong masons are famous for their superb skills. They have the ability for erecting over 60 meters high stone towers. At the same time traditional building materials and tools used in local masonry construction are quite simple.

Local stones and natural mud are the main construction materials of masonry structures. Locals get stones by pounding rocks from

Fig.6. 7 A Tibetan mason was working on a building site, Cong'en, Sha'er Zhong, Sichuan.

nearby mountains. They also dug loess from nearby river banks. At the building site they add water in them to convert the loess into sticky mud. This mud is used for binding stones together to form the structure.

In the local masonry construction process, the most common tools are post-maul, wooden mallet and wooden trowel (Fig.6.7). The post maul is for breaking large stones into smaller rubbles, and the wooden mallet is for beating these rubbles into the mud layer above existing stone walls during the masonry process.

6.1.3.2 Carpentry building technology of local buildings

6.1.3.2.1 Forestry resource

Due to the humid climate in Cha Bao valley, the Sha'er region used to have abundant forest resources in the past. Most of the mountain slopes were covered by virgin forests before 1957. Generally, there are coniferous and broad-leaved mixed forests existing in the regions at the altitude 2700 - 3200 meters, while the evergreen coniferous forests prevail higher regions at altitude between 3200 - 4000 meters. The main tree species of Sha'er regions include: Fir（杉木，Latin: *Abies fabri*）, Larch（松木，Latin: *Larix potaninii*), Spruce（云杉，Latin: *Picea purpurea*), Birch (桦木, Latin: *Betula platyphylla*) and *Qinggan* (青冈，Latin: *Cyclobalanopsis glauca*)（四川省马尔康县地方志编纂委员会 1995, p.169). Nearly all of the virgin forests were cut in the twenty years' logging activities organized by local government after 1957（四川省马尔康县地方志编纂委员会 1995, p.185).

Locals are familiar with the properties of various species of trees. They applied this knowledge on the building constructions and utilized various species of timbers in their construction works. Several species of timbers are commonly applied in the construction projects of local dwellings: birch, fir, spruce, larch, *Qinggan*, and cypress trees. Larch and fir are the most common tree species in local forests. Most of these construction timbers are obtained in the nearby mountains, except cypress. Locals usually bought cypress from outside areas at lower altitudes.

According to the properties of different species of timbers, local carpenters usually used a certain species of timber for making specific building components. They can be classified into timbers used indoor and timbers used outdoors.

i. Timbers used indoor: Larch and fir are mostly utilized as indoor structural members, such as pillars and beams. Spruce or larch are utilized for log-construction granaries.

ii. Timbers used outdoors: Locals believe that both the birch wood and cypress wood are waterproof thus can last longer in damp outdoor environment. Slender birch branches are mostly applied as drying racks surrounding the cantilevered verandas. Fresh and soft birch branches are applied for weaving screens on drying racks. Cypress timber is the preferred material for the pillars of the cantilevered verandas. *Qinggan* wood is used for making cantilevered beams of the verandas, as *Qinggan* wood is stronger than the former two species of wood.

6.1.3.2.2 Logging and log transportation

The annual tree felling period in Sha'er region is spring. After a tree fell, barks were peeled off the trunk to make logs. These logs are stacked on the mountain slope until early winter. During this period the weight of logs decreases due to loss of water.

However it was still a hard task for transporting these dried logs back to the village in Sha'er region in the past. One important limiting factor for log transportation at that period was the population of a village. The scales of Tibetan villages were usually not big. For instance, Cong'en village of this region only consists of nine families in total. As a result, adult men available for transporting logs were usually very few in a Tibetan village. Another important limiting factor was the road condition. Very few good roads allowed the use of animals carrying long logs out of forests in the mountain in the past. Consequently the weight and the length of each construction timber needed to be strictly restricted for transportation as people need to carry them and walk through forests to their village. Lengths of wooden members in ancient dwellings built before the 1950s are mostly less than 5 meters. This situation only changed after the 1970s when trucks were introduced into this region. Many roads with better conditions were built among this region at the same time.

6.1.3.2.3 Carpentry tools

Similar to their masonry tools, local traditional carpentry tools used in building construction are also quite simple(Fig.6.8). Axe, adze, saw, and chisel are already enough for building the wooden structural part in tower dwellings. Planes and other types of more advanced or complicated carpentry tools are only applied in producing the fine indoor furniture and windows.

Fig.6. 8 Tibetan carpentry tools.
(Souce:Ryser,1999,Abb.118)

6.1.3.3 Building process

Traditional tower dwellings of Sha'er region are mostly three to six storeys stone-wood mixed structures. Evidently, building such a tall building demands professional experiences and a big amount of labor works. In the past, the building process of a tower dwelling in Sha’er usually lasted for several years. A house owner would invite at least one experienced masonry master to guide and lead the whole construction process. The master mason and his group were mainly responsible for the main body of the building. Experienced carpenters were invited to build cantilevered verandas, wooden granaries, windows, and some important interior finishes.The owners’ relatives who lived nearby and the neighbors in the same village also came to help with other laborious tasks.

Based on interviews and the detailed study on the seleced study case, Kesha house, the following section tries to reconstruct a complete building process of a traditional tower dwelling in Sha'er.

i. Foundation: (Fig.6.9) House owner and master masons firstly decide the location and interior layout of the dwelling. Builders dig a trench along the outline of furture dwelling. According to the local soil condition, the depth of the trench can reach even three meters when the soil of the ground surface is soft. The habitual width of this trench is around 1 meter.

ii. Wall construction: (Fig.6.10, 11, 12) In order to build a high masonry building, a scaffold is a must in the wall construction process. When building a tower dwelling in Sha'er area the scaffolds are erected inside the surrounding wall, instead of an outer scaffold. Holes for support beams of the former scaffold can still be found in the inner wall surfaces of some local tower dwellings.

The first layer of scaffold is only 1.5 meters high when building the walls of the ground floor. With this height, women who are responsible for carrying mud and rubbles could easily transport them to workers who stand on the scaffold. As the wall rises to around 3 meters during the construction process, workers do floor framing of the first floor. Then they can take apart the lower scaffold, and use the floor framing of the first floor as a working platform. And when the wall rises 1.5 meters higher than the floor of the first floor, workers rebuild a 1.5 meters high scaffold on this floor again. This process will be repeated several times until the total height of the walls reaches the demanded height.

It is recorded that workers were only allowed to build one floor of the dwellings in each year during the whole construction duration (Mao 2005). This tradition could be realized as an approach for minimizing the impact of the shrinkage of the mud layer, aiming to enhance the stability of the construction.

iii. The first-layer cantilevered veranda: (Fig.6.13, 14) In order to install wooden cantilevered verandas in the masonry structure,

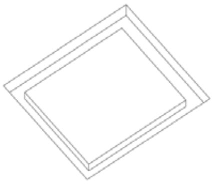


Fig.6. 9 The foundation construction of the tower dwelling

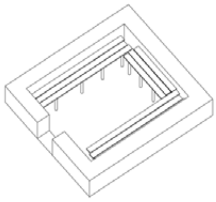


Fig.6. 10 Workers erect short scaffold for building the wall.

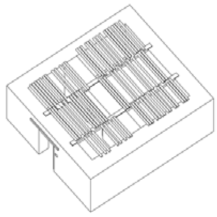


Fig.6. 11 Workers do floor framing of the first floor.

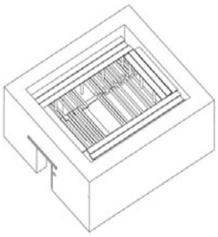


Fig.6. 12 When the wall rises 1.5 meters higher than the floor of the first floor, workers rebuild the 1.5 meters high scaffold on this floor again.

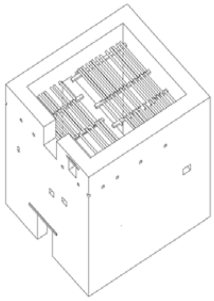


Fig.6. 13 Some holes are reserved for installing cantilevered verandas.

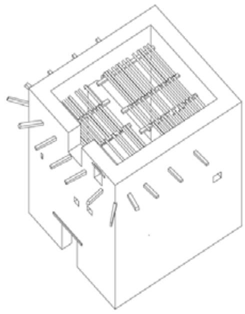


Fig.6. 14 Carpenters install beams into these reserved holes.

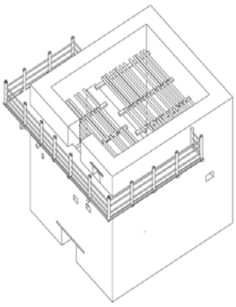


Fig.6. 15 Carpenter erected prepared frames at the outer edges of the verandas, in order to form drying racks.

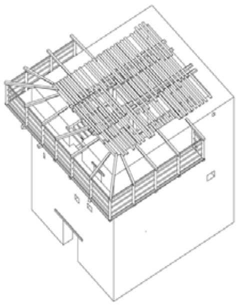


Fig.6. 16 After the last step, carpenters directly lay a series of upper beams above these drying racks.

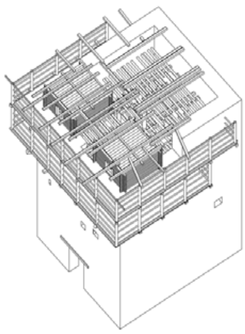


Fig.6. 17 Workers assemble these components to be granaries on this floor.

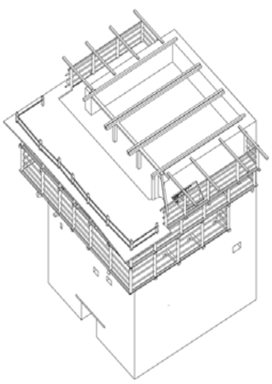


Fig.6. 18 The construction of the topmost floor.

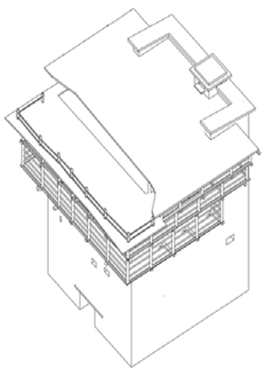


Fig.6. 19 Making floors.

holes should be reserved in the walls' outside during the wall construction process. Roughly shaped beams then are inserted into these holes to form supports for the veranda. Carpenters use wooden wedges between the beams and the holes, aiming to adjust the inclined angle of the cantilevered beams and adjusting the protruding of these beams in the same height.

iv. Erecting drying racks of the veranda: (Fig.6.15) A group of short posts of the verandas and several horizontal drying racks are firstly assembled together to form plane frames. Carpenter then erect these prepared frames at the outer edges of the verandas. They put a beam 'koʑi komɤl' on top of the outside ends of the cantilevered beams. The posts carrying the drying poles were forked at their lower ends and then fixed on the wall- parallel beam beneath. After this step, carpenters directly lay a series of upper beams, which are also the supporting beams of the upper verandas, on the pillars of these drying racks. Load of these upper beams helps these drying racks to keep stable in their places.

v. The second-layer cantilevered veranda and granaries construction: (Fig.6.16, 17) It is supposed that experienced carpenters built log granaries on the ground in advance. When building the second-layer cantilevered veranda and the floor frame of this story, workers take apart log granaries into components on the ground, carry these components to the top of the building, and assemble these components to be granaries on the floor of this storey again. This method reduces the difficulty of processing logs on the unfinished top of the building and allows two groups of workers to work at the same time, which can save construction time.

vi. Topmost structure: (Fig.6.18) The topmost construction consists of the worship room, the terrace, and another cantilevered

Fig.6. 20 The flooring of the dwelling is traditionally composed of several layers: wooden sticks, stone slabs or roughly hewn wooden planks, leaves, rammed earth (from the bottom to the top).

veranda. The skeleton of the worship room is done firstly, and the further refinement work will be done later.

vii. Rammed earth floors: (Fig.6.19, 20) the final step of the construction project is flooring. The floors of the dwelling are traditionally composed of several layers: wooden sticks, stone slabs or roughly hewn wooden planks, leaves, rammed earth (from the bottom to the top). For the floor of the terrace, which needs to resist raining, the thickness of the earth layer should be thicker. Furthermore, a layer of clay in 2 cm thickness will be added on the top of the floor, aiming to improve the rainproof capability of the floor of the terrace. It was usually carried out by a group of women from this village or even neighboring villages in the past. They carried earth to cover each floor frame, and rammed them into rammed earth floor surfaces.

6.1.3.2.4 Remarks

One significant characteristic of the local dwellings is the rough inner structure assembled by short wooden members. The wood component had to be left with a dimension that could be carried out of the forest, over the mountain and handled inside the very restricted space of the narrow buildings. The poor road condition in the past made that locals had to accept and use short timbers in their construction works. Another factor is supposed to be that very little fine carpentry tools were applied in the structural timber work. Many wooden components relied on friction caused by the upper loads to keep stable. And this feature made the building order of the whole construction become important.

Based on the reconstruction of the building process, it became clear that the construction of the granaries was an important step in the whole building process. The inbuilt granaries were closely related to the veranda construction and the terrace construction.

6.2. Tibetan village: Cong'en

The study was carried out in the Cong'en village, a typical Tibetan village located in Cha Bao valley at the altitude of 2700 meters (Fig.6.21). The village consists of only 7 families. The scales of Tibetan villages in this region are generally much smaller than of Han and Dong villages.

Each family owns its own tower dwelling. Under the special land management system of Rgyal-rong region in Tusi period (before 1956) a common farmer family's dwelling was mostly bond to this family's agriculture field (李 锦 ,2010,p11). Both the dwelling and the field were actually the property of a local Tusi, thus the farmers were not allowed to sell or divide these fields, and they were also not allowed to demolish their dwellings freely without the permit of the Tusi. Partly due to this special ownership relationship, some ancient dwellings could still retain their original shapes until now.

Nowadays A local Tibetan family mostly consists of 3-4 people, while the scale of the family was generally much bigger in the past: 7 – 12 people. Agricultural products and livestock form the major income of local families. The division of labor in a family usually was quite clear in the past: men were responsible for grazing, doing business outside or serving for the Tusi, while most of agricultural works and housework were women's duty (西南民族大学西南民族研究院 ,2008,p59). Women still have this duty nowadays, even when men do not need to serve Tusi anymore. This can also be one reason that most agricultural processing activities were arranged to happen close to the dwellings or in the dwellings.

The field area of a family is mostly related to the family's population, which is between 4 *Mu* to 7 *Mu* nowadays. The main agricultural product is highland barley. Meanwhile, radish and beans are also widely planted as a kind of animal feed. After the 1960s, maize and wheat were introduced into this region. The planting area of these two species then increased year after year. Compared with maize and wheat, the yield of highland barley is much less. Locals

Fig.6. 21 The satellite map of Cong'en, Sha'er Zhong, Sichuan.

Fig.6. 22 A public water mill in the village.

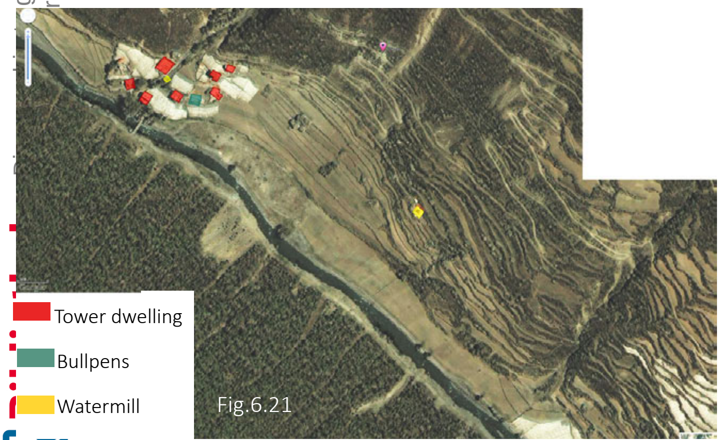


Fig.6.21


Fig.6.22

start to accept maize and wheat as staple foods when the harvest of highland barley in one year is insufficient. In the past they would mostly apply beans and meat to solve the problem of the shortage of highland barley.

6.2.1 Village layout

The layout of the village is closely related to their living style and social background. This village owns quite clear boundaries mostly formed by bushes, rivers, and channels. Seven tower dwellings closely gather together at the junction of two rivers. One public water mill is also located in between (Fig.6.22). Such kind of village layout improves the defensive ability of the village as these tower dwellings can counter enemies from different angles. Location of these tower dwellings rises the convenience of getting drinking water from the river. And this is also more convenient for locals to get to use the public water mill on one of these rivers.

These gathering tower dwellings are surrounded by highland barley fields of the village. Some dwellings own a small vegetable garden on their ground floors, enclosed by low stone walls. Some bullpens are also built beside the dwellings. For villages located in the valley areas, villager's pastures are mostly on the nearby hilltops, where the villager own Alpine meadows

6.2.2 Dwelling and harvest process

Based on the Masonry tradition of Rgyalrong region, tower dwellings are mainly built by stone. In addition, the unsafe society background during the Tusi-period made locals build high and closed stone buildings as their dwellings, deriving obviously from defensive considerations. The floor number of these buildings varies according to the size of a family. Lowest ones own three storeys, and the tallest one can reach seven storey. One ancient tower dwelling in Rangtang region owns nine floors.

Three major functions need to be taken into account when building a tower dwelling in Sha'er in the past: living, agricultural production, and defense. Due to the unsafe local society background and the humid climate, local farmers were inclined to integrate their time-consuming highland barley harvest activities and granaries into their own small fortress, aiming to protect their precious harvest from robbers and rain. In winter time or emergency cases livestock needed to be kept inside the tower dwelling as well. Thus a tower dwelling can be seen as a vertical farm.

However, integrating residential functions and harvest activities in narrow tower dwellings raised some questions to the local builders. The drying process of the highland barley needs good ventilation conditions. The threshing and winnowing need to be in an open area. The grain storage should be located in a dry and well-ventilated area. These conflict with narrow and closed interior plans determined by defensive requirements.

Aiming at solving these problems, carpenters of Sha'er integrated the wooden structure with a stone structure to form a unique type of wood-stone mixed structure in this region. They built overhanging wooden verandas in the upper part of stone tower dwelling for drying grain, built open terrace for threshing and winnowing, and erected log-construction granaries for storing. Effective spatial planning and structure of traditional tower dwelling were developed to adapt a series of agriculture production and storage process besides the living part.

6.2.2.1 A case study of a typical local dwelling

The seven-storey dwelling is one of the oldest building in Sha’er region, which is said to have been built in around the mid-Qing dynasty (1750-1900). As other Tibetan dwellings of Rgyal-rong region built in Tusi-period, the dwelling has its own name: Ke Sha house[3]. (Fig.06.23)

My fieldwork shows that the inner spaces of this building mainly retain its original layout. This dwelling provides a relatively complete example presenting the relationship between the agriculture production and spatial layout of the tower dwelling in a detailed way.

According to the different main functions of each floor, the dwelling could be vertically divided into four sections (Fig. 06.24): the lowest

3. Giving dwellings a special name was a tradition in Rgya Rong region. This can be seen as closely related to the tax system and the land management of Tusi period.

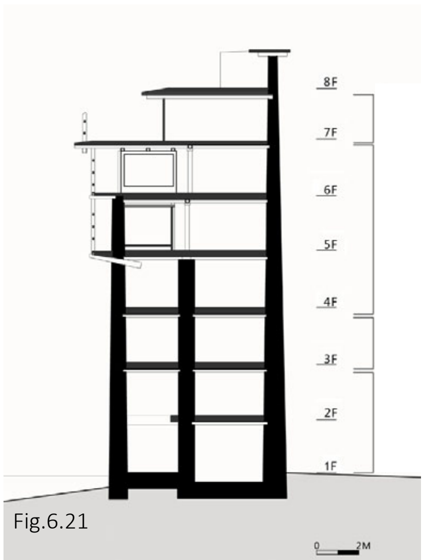


Fig.6. 23 A seven-storey tower dwelling: Ke Sha house.

Fig.6. 24 A section of the tower dwelling.

section is for animals; the middle section is for living; the upper section: for working, storing, and living; the topmost section: for working and worship.

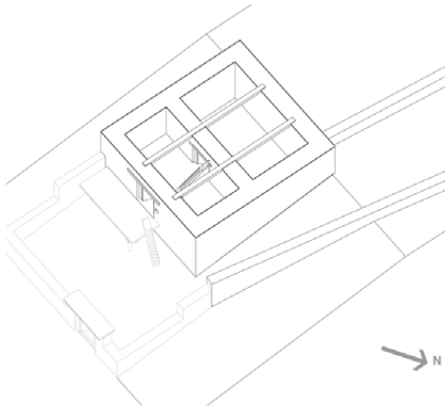


Fig.6. 25 The ground floor.

i. The lower section: (Fig. 6.25;26) There are two floors forming the lower section in Kesha house, while the lower sections of many other later dwellings only own one floor. There used to be a low stone wall surrounding the base, enclosing a private garden for planting vegetable and feeding animals.

The main entrance of the building is opened on the east wall, facing the highland barley field. The inner space of the ground floor is divided into two roughly equal areas by a middle stone wall. The east room of the ground floor is an entrance space with an inclined wooden ladder in the middle. The wooden ladder is made from a whole single log with regular notches. These notches are applied as steps. And the western room was applied for keeping cows and other domestic animals during the cold winter in the past.

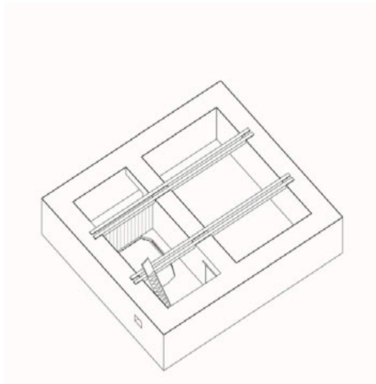


Fig.6. 26 The 1st floor.

The first floor is mainly used for storing hay for the animals. Similar to the ground floor, the 1st floor is also divided into two areas with a middle stone wall. The western room is the main functional area: hay storage, while the east area is mainly the traffic space. There is a small tool room enclosed by a wooden wall at one end of the west area, for storing agricultural tools and carpentry tools.

ii. The middle section: (Fig. 06. 27) the second floor contains the core living space of the whole dwelling: kitchen (Tibetan: khɣjmu, Chinese: 茶室 or 主室). In Rgyalrong region a kitchen is a multifunctional place applied for cooking, dining, and meeting. As one of the most important rooms in the dwelling, the room is rich in decoration. The floor of this room is covered with wooden floor planks. And the wall is also covered with continuous wooden decorative closets, for showing off the wealth of this family. An old open fireplace is in the center of the room floor, and a small steel stove is next to it. This fireplace area is the core of this room, which was applied for cooking and heating in winter time. Behind this main room, there is a minor room in the east area connecting with the kitchen. It is a sub-storeroom for storing Zanba, wine, and other precious foods. The east area is mainly applied as a traffic space.

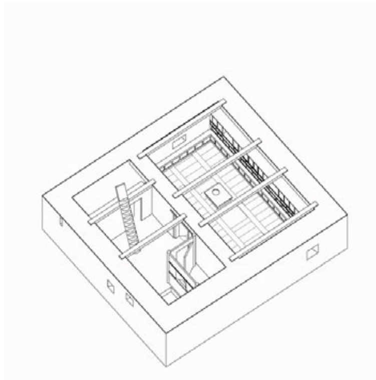


Fig.6. 27 The 2nd floor: kitchen.

iii. The upper section: (Fig. 06. 28;29;30) the third, fourth and fifth stories form the working, living and storage area of this tower dwelling.

The third storeys is mainly for hay storage. The hay in this area are mostly straws of highland barley. They are stored in here after the threshing process on top of the building.

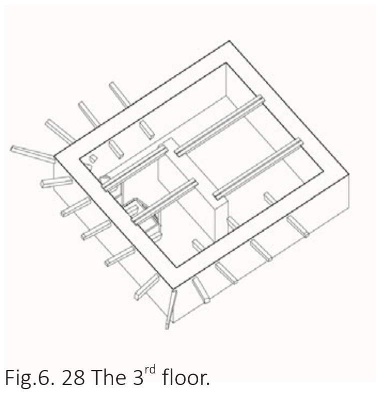


Fig.6. 28 The 3rd floor.

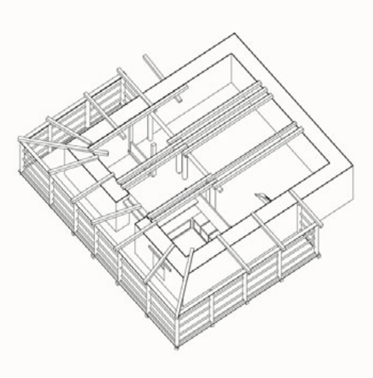


Fig.6. 29 The 4th floor.

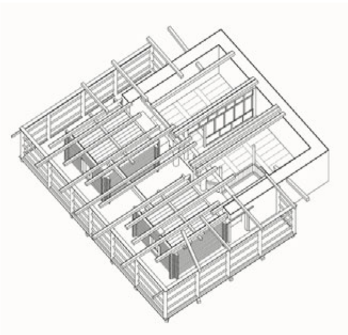


Fig.6. 30 The 5th floor.

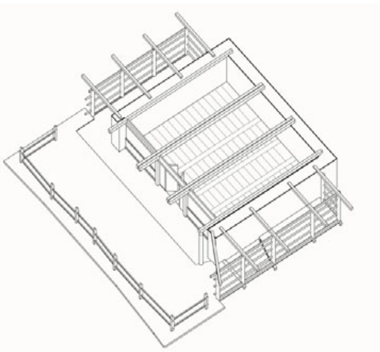


Fig.6. 31 The 6th floor.

The 4th storey is applied for hay storage and food storage. The 4th storey owns an open indoor space, with a small enclosed storage room at the northeast corner. The big open space is mainly applied for storing hay for the animals, while the small storage is for storing dried meat, fur and cereals. Located in the corner, the small storage is enclosed by two sides of wooden planks and two sides of stone walls. The door of the storage is on the eastern stone wall. The orientation of the door of the storage might be related to the lighting needs in the closed storage. The floor of the storage is an elevated wooden floor, which is lift around 20 cm higher than the original rammed earth floor of this story. This aims to provide an air-ventilation layer between the wooden floor of the storage and the original rammed earth.

The indoor space of the 5th storey is divided into two different functional spaces: bedrooms and granaries. The two bedrooms are located in the west area. They are furnished with fine decorative wooden walls and covered with wooden floor. One outer wall of a bedroom was demolished due to unknown reason. On the other side the two log construction granaries with nearly equal plans were built in the east area of the plan. There is one wide short corridor left between the two granaries which was mainly used as a temporary storage place and working place.

Overhanging verandas are built outside the 4th and 5th storey. They are used for drying highland barley in harvest season. In some other seasons they are used for drying radish and beans. It can also be used for storing straw in some cases. I will discuss this part more in detail in section 6.2.3.2.

Instead of stone walls, the 4th and the 5th storeys use wooden pillar and beams as interior supports. Wooden supports help to create a more open space improving the conditions for working indoors. It can also be based on the requirement of reducing the building load and difficulty of construction. More structural details can be seen in section 6.2.3.3.

iv. The topmost storey : (Fig.31) this floor consists of two main functions: worship space and harvest working space.

The front terrace occupies nearly the half area of this plan. It is enclosed by three-sides of wooden fences mainly applied for threshing, winnowing and final drying works of the highland barley. Some other types of harvest products are also dried on the terrace in some cases. Located on the top of the building, the terrace receives most and longest sunshine, which is especially important for the dwellings located in the steep valley area. Compared to the plain area,the duration of sunshine is much shorter. Due to its fundamental function and the environmental factor, the orientation

Fig.6. 32 Short wooden planks were applied to close the wooden fences on the terrace during the harvest period.

Fig.6. 33 A wide porch in front of the worship room, supported by extended beams.

of the terrace is rather important: terraces of most local tower dwellings were designed to face south or east, according to the local terrains.

For threshing working, short wooden planks were applied to close the wooden fences on the terrace, aiming to form a relatively closed enclosing area to prevent the loss of grain during the threshing progress (Fig. 6.32). The rammed earth floor of the terrace was carefully cleaned before the threshing work.Woven mats were laid out to cover on the rammed earth floor, in order to creat a clean surface for the threshing work at some times.

The big room of the topmost storey is named "lecture hall" (经堂). It is mainly for worship and is the most sacred space in the dwelling. Only monks and family members are allowed to enter this space. However, this sacred space is also utilized as a temporary storage for highland barley sometimes during the harvesting period, especially in the case that the threshing work lasts several days.

There is a wide porch in front of the worship room, supported by extended beams. This semi-outdoor space used to be one of the most favorite domestic spaces for local women in the past where they often did some housework during the daytime due to the lack of indoor lighting. This space can be also utilized as temporary storage place for cereals when rain suddenly stop threshing or winnowing process on the terrace (Fig. 6.33). Due to these functional requirements, local builders were inclined to erect a wide porch with the width between 1.2 meters to 2.4 meters on the topmost story.

Two verandas with drying racks are mounted on the two sides of the worship room. On the end of one veranda, there is a hole opened in the floor which is used as a toilet.

There is a wooden ladder leading to the roof of the worship room. A small altar is on the rear low wall of the roof, which is a place for

Fig.6. 34 Two log granaries on the 5th floor of Ke Sha house. (source: Klaus ZWERGER)

daily worshiping gods.

6.2.2.2 Wooden granaries and the dwelling

According to studies on Kesha house and some other ancient dwellings of Sha'er region, the locations of log-granaries in the upper section generally follows a certain pattern(Fig. 6. 34). The wooden granaries are mostly located in the east part or south part of the buildings, in order to could gain more sunshine to ensure better drying condition. This kind of arrangement evidently aims to meet the general requirement of cereal storage. Meanwhile, as a kind of self-supporting structures, log construction granaries can stand independently without any additional support such as stone wall. Thus log-construction granaries usually stand indecently at corners of tower dwellings, keeping a certain distance to stone walls. Due to the moisture produced among the seed respiration process, the internal humidity in the granary increases at times. When the wooden surfaces of granaries are exposed to the air, excessive humidity has the chance to evaporate to the outdoor through the capillary effect of the wooden walls, thus keeping the internal humidity of the granary at a relative low level. This low humidity level is good for the preservation of cereal.

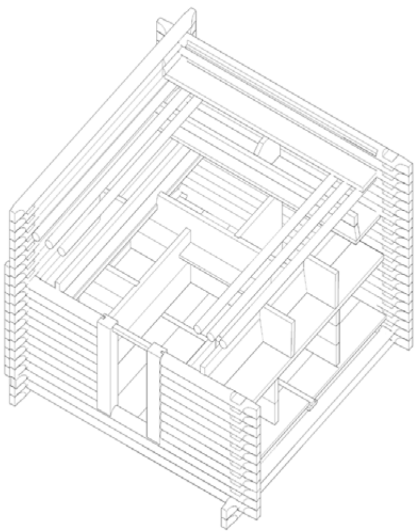


Fig.6. 35 The inner layout of the granary.

The forms of these wooden granaries are similar. Their plans are generally square, with the side length around 2.5 meters. And their heights are also around 2 meters. According to the interview the total volume of each granary for storing highland barley could reach more than 500 kg. The heights of their doors only allow people to stoop to enter the granaries. Inside a granary, several pieces of thick wooden boards divide indoor space into grain chests at different heights (Fig. 6. 35).They contain different units. Local people are inclined to store different type of cereal separately in different units.

The same type of cereal but produced in different years should be stored separately as well. Obviously, this kind of designs relates to the diversity of their staple food in Sha'er region. Above these chests, some horizontal racks form a group of simple shelves. These are for storing dried meat or furs. Honey and some other types of food are stored in the granaries as well.

6.2.2.3 Cantilevered veranda with drying racks

The cantilevered verandas with drying racks are one of the fundamental building elements among the traditional tower dwellings of Sha'er region. It is pronounced as 'jɤɣɤt' in the local dialect (Jacques 2016). With a general width of around 1.2 meters, these verandas are enclosed with wooden fences, which can be used as drying racks during the harvest period. These drying racks can shorten the drying duration of harvest products, which is important for local farmers.Hay produced after threshing is also stored in the veranda when the indoor space is not enough. Outside the harvest period, white birch sticks wrapped by thinner branches are 'woven' into racks forming enclosed surfaces surrounding the verandas. (Fig. 6. 36)This kind of woven enclosing surfaces aims at preventing wind from entering the house (Jacques 2016).

The layout of cantilevered verandas is the result of adapting the local environmental factors. Taking Kesha house, for example, three layers' cantilevered verandas are built on the top of the building. The high place helps them to gain more wind force, thus accelerating the drying process. Meanwhile, long sides of the cantilevered verandas in most of the traditional tower dwellings of Sha'er region face to south or east. This layout aims to gain longer sunshine duration. On the other hand, the asymmetric layout of verandas in some dwellings implies that wind is also an influencing factor for the layout of the cantilevered verandas. In some dwellings, verandas would extend more along the side facing to the main wind direction, aiming to provide more effective drying areas (Fig. 6. 37).

Fig.6. 36 Woven enclosing surfaces of cantilevered verandas.

Fig.6. 37 Plans of a tower dwelling in Sha'er, Sha'er Zhong, Sichuan.

6.2.3.4 Transportation of highland barley in a tower dwelling

In Sha'er region, people used movable ladders to climb up and down through the whole house in the past (Fig. 6. 38). This tradition is still in use last in some old tower dwellings. Logs with regular notches are applied as ladders (Fig. 6. 39), and people get to the upper layer through an opening in the ceiling. One advantage of such primitive log ladders is that it can be done easily by simple tools. Since farmers usually owned only simple tools in this remote area, this is important. In addition, movable log ladders were recognized as part of the defensive system of tower dwellings in the past. These moveable ladders could be removed and hidden when robbers broke into the house. Thus it was thought to be a way to stop robbers from getting on the upper part of the building, where inhabitants preserved their important wealth and food.

Most of openings of these staircases are much bigger than the necessary size to allow one person to pass it by the log ladder. These openings are generally in irregular shapes, with diameters between 2 to 2.6 meters. Considering the narrow and impact indoor space of ordinary tower dwellings, the question arises why locals applied such oversized openings.

Fig.6. 39 A wooden ladder.

Fig.6. 40 A local woman used a rope to carry the bundles of highland barley.

Fig.6. 41 . Locals put a long wooden plank connecting the end of the lowest veranda and the ground floor as an inclined gangway.

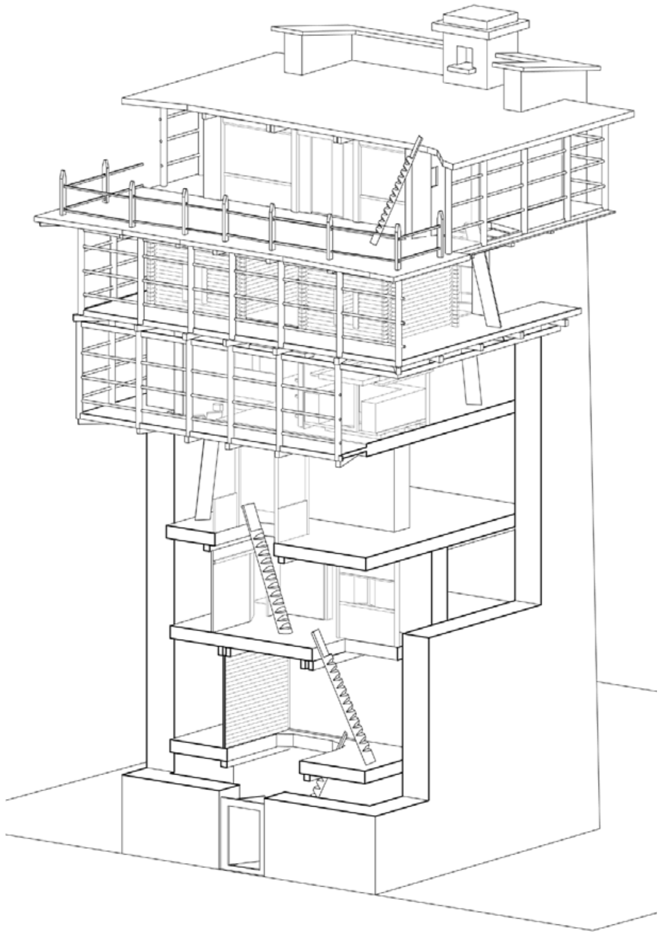


Fig.6. 38 The transportation space in Ke Sha house.

The investigation of the local harvest process reveals that locals usually used a rope to carry the bundle of highland barley on their backs (Fig. 6. 40). Carried this way, ears of highland barley mostly face to outside. When they need to be carried to drying racks on top of the building locals had to to pass through the indoor opening separating the floor. Then ears of highland barley will hit edges of openings inevitably if these openings are too narrow. This will cause loss of the precious harvest. Consequently, we can suppose that these oversize openings are done for preventing such kind of lose.

Some locals built a temporary outdoor short cut to avoid the difficulty of carrying highland barley through the narrow and dark interior space. They put a long wooden plank connecting the end of the lowest veranda and the ground floor as an inclined gangway, take off part of drying racks and carry highland barley through this outdoor passage directly into the veranda. (Fig. 6. 41)Due to the limitation of the length of the plank, this approach could only be applied in dwellings with fewer storeys.

6.2.3 Construction of tower dwellings and its granaries

Many local tower dwellings are built with mixed wood-stone structures. The study of Kesha house reveals that there are four types of structure modes used in a typical tower dwelling of this region: load-bearing stone structure, load-bearing stone structure mixed with inner wooden posts, cantilevered wooden structure, and log structure. Installing wooden structures into a stone structure can reduce the building load, and enlarge the indoor space. But it also could increase structural instability. Detailed analysis of the structure of Kesha shows that local carpenters and masons made great effort to ensure the stability of the whole building.

Log constructions are used as granaries in ancient tower dwellings. They can be seen as a relatively independent part of the whole building. However they also act as import structural component in stabilizing the whole structure and supporting the load.

6.2.3.1 Main structure of the tower dwelling: Stone structure and the inner wooden structure

Aiming at enhance the stiffness of the structures, most of the local tower dwellings apply narrow square plans with thick stone walls. The basement plan of Kesha house is 7.3 meters wide and 8.2 meters long, enclosed by 0.9 meters thick walls. A few holes acting as windows are in the outer walls. The areas of these openings are generally quite small, based on both the defensive requirement and the structural strength requirement.

In the lower storeys of Kesha house, there is a stone wall erected centrally in each floor. As a load-bearing wall, this middle stone wall passes through 4 storeis. They also act as indoor partition walls. Additionally connecting with the outer walls, this stone wall also contributes to resisting the potential lateral loads of the building, thus enhancing the stiffness of the whole structure.

The interior floors of lower storeys are supported by wooden beams carried by stone walls. While in upper floors, the inner wooden pillar-beam system is applied to create an open working space without partition. Comparing with the traditional wooden frameworks of the Dong people or Han people, the wooden pillar-beam system of tower dwellings in Sha'er region owns unique features.

i. The lengths of the wooden structural members in this pillar-beam system are mostly limited to 4 -5 meters. This is closely related to the poor transportation condition in the past. This had been already mentioned in the former section.

ii. Nearly all wooden structural members are executed in a quite rough way. There are very little joints applied for connecting the structural members. The sections of the beams are shaped quite flat, aiming at enlarging the contact face with pillar heads beneath. The stability of such kind of pillar-beam systems relies on gravity and friction primitively and predominantly

6.2.3.2 Cantilevered wooden veranda

Building cantilevered wooden verandas needs experience. This task had to be executed by experienced carpenters in the past. Many local tower dwellings own two or three layers of cantilevered verandas. Detailed investigation shows that the lowest veranda of a tower dwelling not only needs to support its own weight but also the load of the upper verandas. The total amount is an extremely large load. A successful construction of the lowest veranda is essential for the stability of the whole cantilevered wooden verandas. And the diameters of supporting beams and the building method of the lowest veranda are mainly different from the upper ones.

6.2.3.2.1 Construction of the lowermost cantilevered veranda

Supporting beams of the lowest veranda are huge cantilevered beams. They are made of *Qinggan*, a type of hardwood. These beams are installed into the reserved holes in the walls. Half of them puncture the wall and enter the indoor space. The inner ends of the cantilevered beams are mainly pressed by wooden blocks or short beams beneath the ceiling, aiming to ensure the cantilevered beams maintain a certain degree of inclination (Fig.6.42). The inclination from the higher outside to the lower fixation in the wall responds to the load stress. Based on the principle of leverage, one end of a cantilevered beam can be tightly fixed by the stone wall and inner wooden blocks to counteracting the load of the veranda on the other end, without any additional help of wooden joints. In this case, the load of the stone wall above the cantilevered beam, and the load of the floor above the wooden blocks are quite important for the balance of the cantilevered beam. For this reason, I believe that the inner wall of lowermost cantilevered verandas of tower dwellings should always be stone walls. This proved to be true according to my investigation. And this also suggests that the construction of the lowest cantilevered veranda can be only started after the stonework of this floor has been carried out.

Fig.6. 42 The inner ends of the cantilevered beams are mainly pressed by wooden blocks or short beams beneath the ceiling.

6.2.3.2.2 Construction of upper verandas

In most of the tower dwellings, supporting beams of upper layers of verandas are extended outwards horizontally. The outer ends of these supporting beams are supported by lower pillars. Their inner ends are fixed in the stone wall. Construction details show that the inner ends of some beams are firxed by wooden granaries above. In this case the load of wooden granaries helps to keep the whole structure stable.

6.2.3.3 Log constructions as supporting members in tower dwellings

Owing to its independent structural system, log-structure granaries located on the upper floors are a unique structural member in tower dwellings. Taking Kesha house as an instance in its 5th storey, two log-structure granaries are installed in the east area of the floor. They act as supporting structural members to carry the load of the upper terrace, instead of stone walls and wooden pillars. In terms of space organization, such kind of supports can enlarge the available indoor area. Seen from a structural point of view, such supports offer a larger supporting area, thus allow carpenters to arrange upper beams in a more flexible way.

Due to the requirement of façade protection against rain, the roof eave of the top veranda usually extends to 0.8 meter wide outside the drying racks. Detailed study shows that local builders applied a special approach by aid of the log structure beneath to support this extended part and heavy upper load. There are two types of

Fig.6.43

Fig.6.44

Fig.6. 43 Wood pieces are acted as wedges in between uppermost log-building layer and floor supporting beam.

Fig.6. 44 A Tibetan log-granary in Yongzhi, Deqin, Yunnan.

beams above granaries. One type of beams are mostly shorter, only supported by the granaries beneath. While another type is longer, supported by granaries and posts of the outer veranda. The latter usually own three pivot points: two on a granary, one on the top of a post. When we consider the heavy load of the upper floor, we can deduce that load on the inner parts of these beams is larger than on the outer ends. To a certain degree we could address them as cantilevered. They help to reduce load which needs to be carried by out posts of verandas, thus enhancing the stability of the whole cantilevered verandas in a way.

Based on the detailed measurement, we find out that the beams laid on top of the granaries are inclined beams. The outer ends of the beams are higher than the inner ends. And the degree of the slope of those beams is around 3.5°. We assume it should be a very considered measure. People who erected such construction had the experience that the outer ending of the protruding beam gives way to the load above thus inclining downwards. They counteracted in advance by installing the beams slightly inclined. Additionally, the inwardly inclined beams above the granaries would cause the base layer of the floor inclined as well, thus the layer of the rammed earth would become thicker forwards inside to get a horizontal floor. Thus the load laying on ends of these inclined beams also increases, thus ensuring the stability of the whole structure.

There has to be connected another observation. The heavily loaded protruding beams above the granaries firmly press down on them. They put their weight on the log construction thus locking their joints firmly. This should ensure the granaries' optimal sealing. Yet the natural property of wood ensures shrinkage of the stapled logs. Therefore they reduce the granary's overall height resulting in insufficient support of the cantilevered beams above. The deformation of the log building would cause a much more problematic deformation of the terrace floor above. People solved this problem in a very pragmatic way. They insert wood piece acting as wedges in between uppermost log-building layer and floor supporting beam (Fig.6.43). Their amount and size are adapted to necessity. It had to stay abreast of changes.

6.2.3.4 Construction of log granaries

The log construction is one of the most ancient building construction methods in the Tibetan region, which could be dated back to 4000-5000 years ago (保罗 ,1996, p83). It was widely applied in the Tibetan areas with abundant forest resource, such as the Diqing area in Yunnan province and Sha'er area in Sichuan as well.

The log construction was regarded as the ideal construction method for the cereal storage in the Tibetan region since log-granaries were thought to be more stable than wooden granaries based on other constructions.According to the earthquake threat in the Tibetan areas and the unsafe social factors of this region in the past. Robustness and high stability become the primary consideration for the granary construction. Locals believe that the log construction could still survive under the damages of earthquakes even when other parts of the dwellings were damaged which thus protected the precious harvests from being lost (叶启燊 , 1989, p137).

The location of log granaries differs according to the regions: in Diqing area. Log granaries are mostly located independently besides the dwellings (Fig 6.44), while in Sha'er region, they are mostly located on the top of tower dwellings acting as an important part of the building structure.

The study on the building craft of the log-construction granaries is still insufficient until now. Although many records mentioned the existence of log constructions in Tibetan dwellings, very few further studies on the building craft of this construction were processed. Most of the researchers held the opinion that the Tibetan log construction was a primary and rough building craft which is not worth detailed studying. However, when someone has a closer look at the construction of these granaries, he will get the opposite idea. Compared to interior pillar-beam structures of tower dwellings ,constructions of granaries are done in a much more precise way. The construction of log granaries fairly relies on the carpenters' specialized skill and working experience on log construction, which has been almost lost in the current generation. In my fieldwork, more than one Tibetan carpenters of Sha'er region admit that it is a hard task for them to build a log-construction granary now.

Traditionally, there are two species of wood mostly applied for the granary construction: spruce and larch. The abundant resource of

Fig.6. 45 Thick wooden planks are also used for building log constructions in some cases.

these two species of trees in the Sha'er region is one reason that they have become the preferred wood for log construction. Apart from their abundant availability their straight shapes were needed. This reduces the labor of preparing the building material.

The log-construction granaries existing in the dwellings of the Sha’er region are mostly not so big: 2.5-3 meters long, and 2 meters high. Applying short timbers in building construction reduces the difficulty of transportation. Furthermore, it also reduces the possibility of structural deformation.

Based on a detailed measurement on a granary of Kesha house, the following parts aim to provide further information about log-construction granaries of this region.

i. **Log walls:** Logs applied in one granary are mostly of similar dimension. Their original diameter is generally around 12 cm. Carpenters roughly hewed the top and bottom sides of each log into flat planes, aiming at stabilizing the structure and reducing gaps between logs. Thick wooden planks are also used for building log constructions in some rare cases (Fig 6.45). In some granaries, it could be found that a mixture of mud and cow dung was utilized to be infilled between the logs of the granaries, primarily for improving the tightness of granaries.

ii. **Corner work**: (Fig 6.46) corner connections of granaries in Sha’er area are mostly made in the same way. A typical corner connection utilizes a kind of lock notching method with a different upper surface and lower surfaces. The mating surface of the upper side of the joint is done rougher than of the side facing downwards, while the outline of its opening is hewn carefully into curved shapes, aiming at fitting the outline of the upper log. The flat step of the notch of the lower side is also developed to enhance the overlapping joints fitting more tightly.

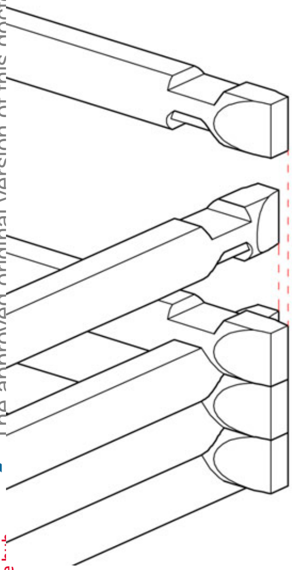


Fig.6. 46 Construction detail of the corner work of a log-granary in Kesha house.

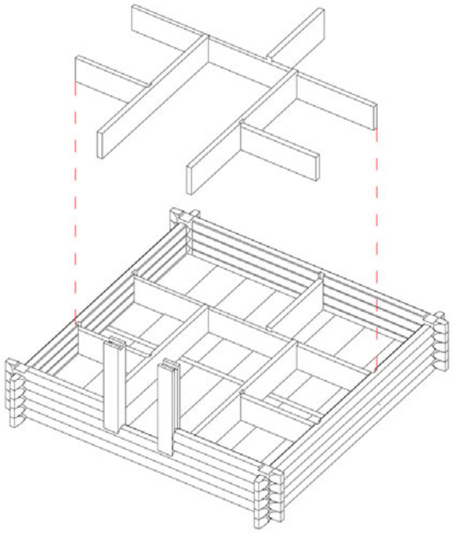


Fig.6.47

Fig.6.48

Fig.6. 47 Inner cabinets are generally made by thick planks installed inside the prefabricated grooves on the inner wall surface of the granary.

Fig.6. 48 The interior of a log-granary

iii. **Inner cabinets**: (Fig 6.47.48) inner cabinets are generally made by thick planks installed inside the prefabricated grooves on inner wall surface of the granary. Additionally, these inner divisions also act as reinforcement inside the granary, improving the stability of the whole construction.

iv. **Door:** (Fig 6.49) doors of log granaries are generally fairly small: 0.9 meters high and 0.5 meters wide. For entering the door, people should bend, being aware that this causes inconvenience. Due explanation concern the stability of the construction. A low door mean less logs cut through for the installation of the entrance. Meanwhile, the short height of the door could also reduce the impact of the uneven shrinkage between vertical door posts and horizontal logs, which might cause structural deformation. According to the detailed examination on joints of doors, it shows that both ends of door posts are cut into fork shapes, and logs beneath and above the door are dug out pairs of notches in order to fit the fork ends of two doorposts.

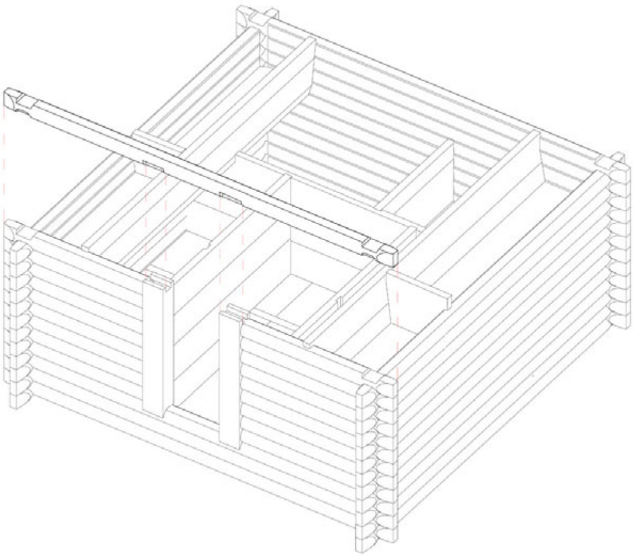


Fig.6. 49 Construction detail of the door of a log-granary in Kesha house.

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List of Figures

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