

Traditional Chinese Vernacular Dwellings: Architectural Features of Nanjing Tulou

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Abstract

Nanjing Tulou (also known as Nanjing Earth Building) is one of the representative buildings in traditional Chinese vernacular dwellings. It is characterized by the use of local soil and materials, simple structures that are practical, durable, and resistant to natural disasters. Its architectural features make it a unique example of Chinese architecture. This article mainly analyzes the materials and architectural structures of Nanjing Tulou. The research findings indicate that the materials used by the Hakka people in Nanjing to build traditional Tulou mainly come from the abundant local resources of soil, wood, and sandstone in the mountainous areas. Adapting to local conditions integrates the architecture with the local environment. Due to the selection of materials close to nature, the architectural form presented by Nanjing Tulou is more primitive. The massive volume of the roofs and earth walls gives an overall impression of heaviness. The external structure presents a combination of square and circular shapes that resonate with traditional Chinese culture. Nanjing Tulou is an important research subject in traditional Chinese vernacular dwellings, and studying it can promote the development and attention to traditional Chinese residential architecture.

Keywords: *Nanjing Tulou, Architecture, Traditional Vernacular Dwellings, Architectural Structure*

INTRODUCTION

Traditional Chinese vernacular dwellings are an important carrier of traditional Chinese culture, reflecting various influences such as China's geographical environment, climate characteristics, lifestyle habits, social systems, and aesthetic concepts. Traditional Chinese vernacular dwellings exhibit distinct regional characteristics. For example, the water town residences in the Jiangnan region, such as the garden-style homes in Suzhou and the waterside residences in Zhouzhuang and Wuzhen; Beijing's courtyard houses; the cave dwellings in Shanxi; the Tusi (chieftain) residences in Hunan; and the Tulou in Fujian.

The earliest documented mention of Tulou dates back to the Ming Dynasty. The "Reconstruction of Qiantai" records that in the 38th year of Jiajing (1559), bandits in western Fujian built two Fujian roundhouses at the junction of Yong'an and Liancheng, which is one of the earliest records of Fujian Tulou. In the Ming Wanli era (1573), the "Zhangzhou Prefecture Annals" listed the number of local Tulou, earth fortresses, and earth villages in an official historical document. The annals included investigation data announced and recorded by the then magistrate Luo Qingxiao: "Since the 40th year of Jiajing, banditry has been on the rise, and civilian-built earth walls and earth buildings have increased, especially in coastal areas... Longxi County has three earth castles, eighteen earth buildings, six earth enclosures; Zhangpu County has five inspection office earth castles, fifteen earth fortresses; Zhao'an County has three inspection office earth castles, two earth fortresses; Haicheng County has three inspection office earth castles, nine earth fortresses, three earth buildings." (Huang, 2019) This document illustrates the strong attention given to Tulou construction at that time.

During the Chongzhen period of the Ming Dynasty, the "Haicheng County Annals" recorded Huang Wenhao, a Jinshi scholar in the 35th year of Jiajing, who wrote a poem "Ode to Tulou":

*"Leaning against the mountain to form a city,
Cutting wood to make weapons to guard the empty tower.*

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Crossing layers with swords like a tiger's gaze and a dragon's leap,

Viewing the enemy as if they were ants, sighing.

All around are like this, how can they be trapped in Changping?

Why abandon danger and obstacles, not defending?

Hearing the tigers and wolves, the heart is alarmed.

The ancient saying there are many talents in Minzhong region,

How can there be no one to lead the troops?

Who can turn weapons into farming tools?

I will rely on them as a barrier."(Chen, 1762)

This document describes the role, function, and characteristics of Fujian Tulou.

Research on Fujian Tulou in modern times first appeared in an article titled "Dwellings of the Hakka in Yongding County of Fujian Province" published in April 1957 by Zhang Buqian, Zhu Mingquan, and Hu Zhanlie. The article featured the architectural forms of Hakka Tulou in Yongding, making it the earliest academic research article on Fujian Tulou. (Fang, 1993) The article did not mention specific information about Nanjing Tulou. In the same year, Professor Liu Dunzhen published "An Overview of Chinese Residences," which, for the first time, classified and defined Tulou typologically. These works were combined and published by the Japanese Kashima Publishing Company in "Residences in China." Additionally, in 1971, Joseph Needham introduced the "Most Distinctive Chinese Residences" - Hakka residences in Fujian Province in Volume 4, Book 3 of "Science and Civilization in China." (Needham & Ronan, 1978) The emergence of these articles gradually brought attention to Fujian Tulou in the global architectural community.

Fujian Tulou, both in quantity and quality, has its unique charm. Regarding the origin of Fujian Tulou, there are currently two main conclusions: the "Hakka theory" and the "Min Nan theory." Hakka Tulou was "discovered" over 50 years ago, while Min Nan Tulou has only gained recognition in the past 20 years. In terms of popularity, the Hakka theory is dominant - coupled with the strong promotion of Hakka culture, Tulou has essentially become the most important symbol of Hakka culture. This article mainly focuses on the analysis and exploration of the architectural features of Nanjing Tulou.

Nanjing Tulou

Nanjing Tulou is an important representative of Traditional Chinese vernacular dwellings and one of the unique mountain village residential buildings in the world. It is mainly distributed in the mountainous towns of Shuyang, Meilin, and Kuyang in Nanjing County, Fujian Province, which are adjacent to the Minnan region. Among them, Shuyang Town has the most Tulou with a total of 92 ancient Tulou, accounting for 41% of the ancient Tulou in Nanjing County. In the study of Nanjing Tulou, Mr. Huang Hanmin must be mentioned. During his field survey in the Minnan mountainous area, he discovered the hidden Tulou in the Nanjing area of Minnan. Subsequently, in 1982, he published "Traditional Features and Local Styles of Fujian Residences," which was serialized in the 19th issue of "Architect" in 1984, marking the beginning of the research on Nanjing Tulou. In the late 1980s, due to domestic and international media coverage, Hakka Tulou became famous, and the fame of Hakka Tulou far exceeded that of the later-discovered Minnan Tulou. In 1988, Mr. Huang Hanmin proposed that the roots of round Tulou are in Zhangzhou after research and analysis. He believed that round Tulou may not be exclusive to the Hakka people. Various counties in Zhangzhou, mainly inhabited by Minnan people, have more round Tulou than Hakka round Tulou. This conclusion was supported by many scholars, represented by Zeng Wuyue, but it also sparked dissent among many scholars, represented by Fang Wen and Lin Zhu. Of course, aside from the controversial origins of round Tulou, defining Tulou is also quite challenging.

Japanese architect Toyo Ito was deeply impressed by these buildings, especially when he saw the Tianluokeng Tulou Cluster in Nanjing, directly referring to these clustered landscapes as "mushrooms sprouting from the

ground" or "flying saucers in the sky." In his book "Family, Feng Shui, and Tulou," he pointed out: "Among the terraced valleys, protruding from the curved riverbanks, they appear like huge 'mushrooms' naturally growing out of the ground, with round earthen walls scattered among the mountains. It is as if they were black 'flying saucers' (UFOs) descending from the sky, with circular roofs floating and rippling in the mist." (Zhen, 2007) These references indicate the architectural features of Nanjing Tulou have significant research value. Mr. Luo Zhe Wen, a senior engineer at the Chinese Academy of Cultural Heritage, after multiple inspections, has made several evaluations of Nanjing Tulou: "They may seem uniform, but they are actually diverse, each with its own characteristics," and "They are marvels in the history of world architecture." In particular, regarding the Tianluokeng Tulou Cluster in Nanjing Tulou, Mr. Luo Zhe Wen described it as "overhead resembling a flower, and from the side, it looks like Potala Palace." This led to the nickname for Fujian Tulou - "Four Dishes and One Soup" - referring to the Tianluokeng Tulou Cluster. Neville Agnew, Deputy Director of the Getty Conservation Institute in the United States, visited Fujian Nanjing to inspect Fujian Tulou. He said, "These are the most beautiful folk buildings I have seen that harmonize with their surroundings." On July 6, 2008, at the 32nd World Heritage Committee meeting held in Quebec City, Canada, "Fujian Tulou" was officially included in the World Heritage List. Forty-six Fujian Tulou sites were formally listed on the World Heritage List, including the Tianluokeng Tulou Cluster and Hekeng Tulou Cluster in Nanjing, as well as Huaiyuan Building and Hui Building. In 2018, the People's Government of Nanjing County compiled "Fujian Tulou · Hometown Nanjing," which continues Mr. Luo Zhe Wen's preface and has been re-drafted by Huang Hanmin. Through a combination of pictorial descriptions and textual narratives focusing on the distribution and quantity of Nanjing Tulou, its history and development, tulou architectural art and features, and cultural landscapes, a comprehensive description has been provided. (Nanjing County Committee of the Communist Party of China & Government, 2018)

CHARACTERISTICS OF BUILDING MATERIALS IN NANJING TULOU

The materials used by the Hakka people in Nanjing to build traditional Tulou mainly come from the abundant local resources of soil, wood, and sandstone in the mountainous areas. These materials are mainly reflected in the Tulou roof, walls (earthen walls), wooden components, and main entrance. Among them, walls, roofs, and wooden components are the main materials.

Wall Materials

Rammed earth walls are mainly divided into ordinary rammed earth walls and adobe walls based on the material composition and ramming process (Table 1). The former is built by ramming local fine red soil, field mud, old wall mud, and broken bricks and stones mixed with water to a suitable moisture content; the latter is constructed by ramming local fine red soil, lime, and sand in certain proportions. Some Tulou buildings also use glutinous rice, brown sugar, and egg white as additives to enhance the toughness of the walls.

Table 1. Types and composition of earth wall materials

	Category	Materials	Alternative Additives	Practice
Wall Materials	Ordinary Rammed Earth Walls	Fine Red Soil; Field Mud; Old Wall Mud; Broken Bricks and Stones	Glutinous Rice; Brown Sugar; Egg White	Mix with water to a suitable moisture content and then rammed.
	Adobe Walls	Fine Red Soil; Lime; Sand		

The local soil in Nanjing is mainly red soil, typically brown-red or yellow in color. Red soil tends to expand and has high stickiness when exposed to water, but it shrinks and cracks easily when dry. Therefore, in the construction of Nanjing Tulou, a certain amount of field mud (also known as "field bottom mud," generally uncultivated soil from paddy fields), old wall mud (abandoned rammed earth), river sand, lime, and other materials are used as aggregates. Some Tulou buildings even use glutinous rice, brown sugar, and egg white as adhesives and curing agents. The materials are proportioned reasonably according to the differences in soil quality in various regions.

It is important to note that in the process of mixing these raw materials, there is a significant step known as "ripening." This is because the collected red soil and other materials cannot be used directly and need to be continuously mixed, watered, turned over, and finely ground. The ripening process usually takes three to five days, and straw is often added at night to prevent moisture evaporation. Sometimes these soil materials are left to mature for several years, requiring continuous turning during this period. Through this process, the soil blends thoroughly. When the prepared rammed earth material is ready, the wall construction process begins by ramming the earth walls (referred to as "xingqiang" by the Hakka people). Wall tamping tools (referred to as "qiangkuai" by the Hakka people) and other complementary tools are used during the construction. Each section of the earth wall is called a "ban," and bamboo or cedar strips are used between each section for connection, known as "tuogu" by the Hakka people. This not only strengthens the structure but also enhances the overall integrity of the wall surface.

In square Tulou buildings, the corners of the outer walls require special reinforcement. Typically, thicker cedar bars or long wooden boards are used to form an "L" shape (referred to as "gougu" locally), buried into the wall. A set of "gougu" is placed every three sections of earth wall to enhance the overall integrity of the wall corners. This reinforcement method is widespread in Tulou construction and is one of the key reasons why Tulou buildings can withstand natural disasters.

The corners of the earth walls are sometimes reinforced with cobblestones sourced from rivers. These stones, after processing and placement, not only serve as flood protection but also support the earth walls, enhancing their stability. Additionally, as cobblestones are a natural stone material with high hardness and durability, they are resistant to environmental erosion. Therefore, using cobblestones as materials for the corners of earth walls can effectively improve their flood resistance, seismic performance, and prolong their lifespan.

Roof Materials

The roof of Nanjing Tulou is mainly made of small blue tiles and blue bricks fired from clay, laid on wooden beams. Clay is a natural soil material containing clay minerals, which is inherently plastic but hardens and becomes brittle when dried or fired. In the selection of clay, it can be sourced locally or transported from elsewhere, generally depending on the family's economic conditions. The selected clay is processed, shaped, dried, and fired to produce the small blue tiles needed for the Tulou, with the color after molding not being blue but dark blue or gray-blue, appearing close to black from a distance. These small blue tiles are laid according to the different roof shape requirements, creating the unique appearance of the roof.

In the production of blue bricks, clay is usually mixed with water to make brick blanks, which are then fired in a brick kiln (at temperatures generally ranging from 900°C to 1100°C for 8-15 days) to make bricks. The fired blue bricks are generally dark blue-black, with high density, no deformation, and no color change, usually serving to reinforce the roof when placed on the small blue tiles.

They effectively prevent rainwater from seeping into the interior and help maintain indoor temperature. In addition, these blue tiles have fire-resistant properties due to the clay itself, providing fire protection. The fresh and natural color of the blue tiles gives a simple and fresh feeling, as well as a sense of stability and antiquity.

Wood Component Materials

The wood components of Nanjing Tulou are mostly made of locally common cedar wood. Cedar wood is preferred because it thrives in warm, humid conditions, is shade-tolerant, and suits the climate in Nanjing. Cedar wood is typically yellow-white in color, with excellent quality, moderate hardness, ease of processing, corrosion resistance, and a faint fragrance. These excellent characteristics make cedar wood an ideal material for the wood components of Nanjing Tulou. In the various wood components of Nanjing Tulou, cedar wood is widely used and crafted into various forms and functions, with processing ranging from simple to intricate. These cedar-based wood materials give Nanjing Tulou a more robust, durable, and rustic character.

Main Gate, Stone Steps, Foundation Materials

In the construction of the main gate, stone steps, and foundation materials of Nanjing Tulou, bluestone plays

a major role. Bluestone is a common type of stone in Nanjing, usually sourced from local rivers. Bluestone has a fine texture and is primarily blue or emerald green in color. Despite being light in weight, bluestone is hard, heat-insulating, corrosion-resistant, wear-resistant, and resistant to weathering. It has a smooth, glossy, non-porous surface, making it a natural cultural and decorative stone. Its application in Tulou is not only due to its excellent texture but also because of its stable physical and chemical properties, allowing it to withstand the complex living environment of Tulou. Therefore, the use of bluestone not only adds a natural beauty to Tulou but also demonstrates the meticulous selection of materials and cultural heritage in the construction of Tulou by the Hakka people in Nanjing.

Materials for Other Areas

The materials used in the main areas of Nanjing Tulou are mainly pebbles, white lime, metals, and other materials collected from local rivers or streams. Among them, pebbles have the natural stone characteristics of compression resistance, wear resistance, and corrosion resistance, making them an ideal green building material. The Hakka people in Nanjing utilize these good physical and chemical properties of pebbles to pave courtyards, making the courtyard ground sturdy, neat, and colorful. In addition to paving courtyards, pebbles can also be used in wall corners or foundations.

In summary, the materials such as soil, wood, sand, and stones used in Nanjing Tulou, although processed to some extent, still adhere to the characteristics of the original materials, providing a safe and comfortable living environment for the Hakka people in Nanjing. These materials have their own natural physical properties and, in the unique cultural background of the Hakka people in Nanjing, convey their unique living traditions and reflect the traditional Chinese cultural connotations of "harmony between man and nature" and "the unity of heaven and humanity." Therefore, Nanjing Tulou is not only a unique residential architectural form but also an important part of traditional Chinese culture.

Characteristics of the Architectural Structure of Nanjing Tulou

External Appearance

The materials selected for Nanjing Tulou are closer to nature, so the architectural form presented is more primitive, and due to the massive volume of the roof and earthen walls, the overall appearance is rather heavy. In terms of the internal structural design, Nanjing Tulou adheres to the main features of traditional Chinese architectural structure - wooden structure, with its structural form manifested as a post-and-lintel construction. Looking at the characteristics reflected by these wooden structures in Nanjing Tulou, the overall workmanship appears simple and the construction is relatively straightforward. Additionally, certain decorative features are also evident in the internal and external architectural elements of the Tulou, reflecting both the dominant traditional Chinese cultural concepts (Han cultural concepts) and the unique aesthetic taste of the Hakka people.

External Image Characteristics

According to the typical morphological characteristics of Square building in Nanjing Tulou, as shown in Figure 1 below. The top image is the first group, showing the most basic '口' (mouth) shape (or '回' shape), which is relatively simple, retaining only the main house part of the square outer ring and using it as a basis to divide the central courtyard and inner courtyard, forming the overall solid exterior and hollow interior form of the Tulou. The middle group is a '口' frame, slightly differentiated inside, and in a rectangular shape. The left image is divided vertically by lines, while the right image only has slight differentiation at the top and bottom lines. The next two groups take the '口' shape as the basic feature and combine and modify it. For example, the left side and Guilou are divided into upper and lower '口' shapes, with the upper '口' shape presenting a mouth within a mouth feature due to the construction of the ancestral hall. Zhen De Lou on the right is also divided into upper and lower parts, with only slight changes at the dividing line.

Overall, these three groups of buildings are based on variations and combinations of the '口' shape and exhibit character-like properties. The first group is in the shape of a '口', the left side of the second group remains in a '口' shape but flattened in form, while the right side has a shape resembling '日' (sun). In the third group, the

upper part on the left is like '回' while overall resembling '日', and on the right side, it resembles '日'. This enclosed style of housing is called '厝' by the locals. Furthermore, from the perspective of Pierce's semiotics, this '口' shaped architectural form not only fits the shape of '口' in appearance but also corresponds to the Chinese meaning of '口' in terms of its function (from a semantic point of view, '口' in Chinese itself means mouth. The mouth can store food and also refers to entry and exit, which is also a basic function of architecture)(Figure 3).



Figure 1. Typical form of square earth building

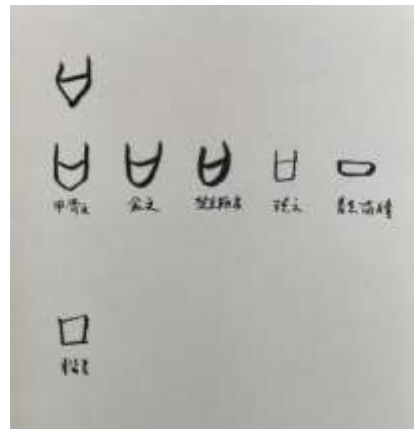


Figure 2. Different Chinese character forms of '口'

The circular earth building is a modification of the square earth building shape, including a perfect circle and irregular circles based on the perfect circle. According to the research conclusion of scholar Huang Hanmin: for the Hakka people, square earth buildings came before circular earth buildings, and circular earth buildings were developed from square earth buildings. The first step in constructing this type of earth building is to remove the corners of the square earth building and make them smooth. The shape of the circular earth building also has the characteristics of the '口' character, but it is more abstract in sensation. Combining Liu Dunzhen's summary of the floor plan shapes of earth buildings, Nanjing Tulou can also be divided into three groups (as shown in the figure below). The top group is a basic circle, characterized by different proportions of the outer ring formed by the earth walls and roof in the overall area. The outer ring on the left is larger, while the one on the right is smaller. The middle group consists of two combined circular shapes, with the proportion of ring lines also reflecting a double proportion of inner and outer rings. The center of the left image features a combination of a circle and a fan shape. The bottom group is the most complex, with the outer ring maintaining a circular '口' shape, while the interior consists of scattered arcs. These arcs, together with the outer ring lines, form the overall architectural form and share the center, reflecting both unity and distinctive characteristics.

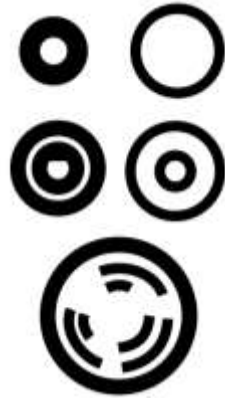


Figure 3. Typical shape of round earth building

The Tianluokeng Tulou belongs to the most minimalist circular or square shapes (although each earth building has an ancestral hall inside, the area is relatively small, so it is not referenced here)(Figure 4). Among them, Zhenchang Building, Ruiyun Building, and Hechang Building are perfect circles or close to perfect circles, while Wenchang Building is elliptical, and Buyun Building is a square building.



(Xiao, 2019)

Figure 4. Aerial view of Tianluokeng Tulou

From the external facade of Nanjing Tulou's architectural shape, although the complexity of the Tulou style shape, looking at the external shape presented by a single building, it can still be summarized as a shape mainly composed of roofs and earthen walls. Taking the five earth buildings in Tianluokeng Earth Building as an example(Figure 5), the overall roof above is trapezoidal, with the left and right sides of the trapezoid sloping outward. This is mainly due to the construction method of the two-sided slope of traditional Chinese architectural roofs. The outer perimeter line of the earthen walls slopes inward from bottom to top, based on the architectural feature of the Tulou being divided from bottom to top. In addition, the roof decorated with tiles also reflects distinctive features: first, the blue tile roof and the wall part have eaves of more than 2 meters; second, the ridge and eaves lines are prominent and strong; third, the roof presents a dense feature due to the combination of tiles. In addition, the four circular buildings in Tianluokeng Earth Building are arched, while the central square building is square. The lower side of the door is the base of the earth building, which appears rectangular from the facade and is built with pebbles or bluestones.



(LHuillier, 2010)

Figure 5. Tianluokeng Tulou front view

As a whole, the exterior of Nanjing Tulou is mainly composed of the wall part and the roof part. The wall part includes stone wall corners, earthen walls, bluestone or wooden doors, window openings, etc., while the roof is made up of small blue tiles and blue bricks. The blue bricks become pressure tiles because they are pressed on the small blue tiles. The windows on the walls are generally arranged horizontally or in an approximate horizontal arrangement, as shown in the figure below (Figure 6). In terms of their distribution, they are irregular but have a certain regularity. These windows are organized into relatively uniform arrangements in single or multiple groups, but the distances between groups vary in size; the windows are generally distributed on the second and third floors. Since the area of the window openings is relatively small compared to the wall area, but the external concrete color with paint is relatively prominent, it overall decorates the black-gray roofs and the yellow-red earth buildings.

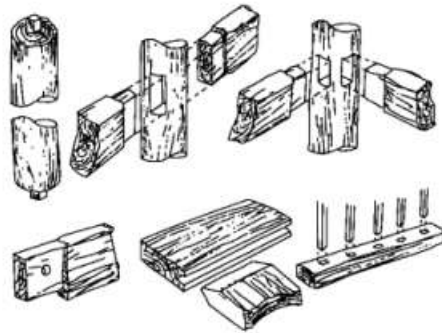


Figure 6. The earth wall of Ruiyun Building & Buyun Building

Internal Wooden Structure

The internal wooden structure refers to the wooden structure inside a building, typically used to support the walls, roof, and floors of the building. In Nanjing Tulou, the wooden structure features a combination of large and small wooden systems. The large wood serves as the backbone system of the ancient Chinese wooden structure, as the dimensions of the wooden components used in the building, such as beams and columns, are large, hence referred to as large wood. The small wood serves as auxiliary components with smaller dimensions. In general, the large wood plays a major role in supporting, connecting, and other main functions of wooden components, while the small wood mainly serves decorative or auxiliary functions. Both types of wooden

structures make use of traditional Chinese woodworking connections - mortise and tenon joints (Figure 7) . In Nanjing Tulou, the wooden structure is built on the basis of combining with the earthen walls.



(Li, 2011)

Figure 7. Mortise and tenon construction unearthed from the Hemudu site

The Large Wooden Structure

The Nanjing Tulou is a multi-story building with 3-5 floors. The large wooden structures on each floor are consistent but differentiated due to their different functions, mainly divided into the top floor and non-top floors. The non-top floors mainly include wooden components such as columns, beams, and tiebeam, constructed using mortise and tenon-based building techniques, supplemented by bundling and stacking methods. The wooden components of the top floor are constructed using a through-tenon structure system, including penetrating tie, purlins, beams, and brackets.

Overall, Nanjing Tulou can be summarized as an evolution of the column and tie construction structure under the constraints of multi-story buildings and external load-bearing walls. (Wu, 2017a) In terms of the vertical load-bearing columns in Nanjing Tulou, they are generally not continuous but are interrupted based on the division requirements between floors, while maintaining the centerline of each column on the same vertical axis. These columns extend from the ground floor to the top floor and are connected to the main penetrating tie (the penetrating tie that primarily bears the roof load, with other upper-level penetrating tie named secondary penetrating tie), named as "hypostyle column" here. The hypostyle columns show a gradual decreasing trend from bottom to top (with some exceptions, such as the top floor of Buyun Building at 2.8 meters compared to 2.65 meters on the 2nd floor). The main through-beams (Named as through beams because they penetrate into the interior of the earthen walls, the beams are called through beams. The main through-beam on the columns primarily bears the load between floors, hence it is named the main through-beam, while other through-beams are secondary through-beams) separate the columns from the earthen walls.

Starting from the first floor, the main through-beam extends outwards, with the extension of bracket connecting to the second-floor columns, connected by mortise and tenon joints, and surrounded by peripheral hypostyle columns to form a corridor. The second-floor columns connect to the outer hypostyle columns and extend all the way to the top-floor main through-lintel using mortise and tenon joints. (Hand-drawn drawing 1 in Table 2) The second-floor main through-beam continues the extension of bracket from the first-floor main through-beam, with a smaller extension length than other floors. Near the courtyard side of the second floor's extension, there are columns connected by mortise and tenon joints, appearing as eaves or king posts depending on the floor level. If the floor has 3 levels, the columns are connected to the roof eaves purlins using mortise and tenon joints; if it is above 3 levels, a waist bracket (Hand-drawn drawing 2 in Table 2) is added, constructed with king post, small penetrating tie, and purlins using a column and tie style structure. The top-floor wooden frame is characterized by a unique face shape formed by penetrating tie, eaves columns, and hypostyle columns, connected by purlins to form the top-level framework. The structure is generally an eleven or nine purlins column and tie style wooden frame without raising the purlin. (Wu, 2017a) Horizontally, the entasis on the tops of the columns show a slight concave shape for supporting the main through-beam. Between columns, there

are Dou tiebeams joints (different from the top column and tie structure of penetrating tie), forming a circle based on the enclosure nature of the building. The Dou tiebeams are spaced at the length of the house's width, with concave entasis at both ends to align with the columns. (Hand-drawn drawing 3 in Table 2) Above the Dou tiebeams are secondary through-beam, equal in length to the main through-beam but with a smaller or equal cross-section. There are generally 2-3 of them, but 5-6 at the ancestral hall. Generally, mortise slots are opened on both sides of the flat entasis in the upper part of the through-beam for laying floorboards. In terms of shape, each floor's columns are relatively simple, retaining the original form of fir wood columns. At the first floor, there are cylindrical stone column bases made of bluestone; above the second floor, there are no column bases, and each floor has plinth stone connected to the columns in mortise and tenon form. The entasis of through-beams is flat at the top and bottom, with a curved profile on both sides and a straight profile top and bottom, connected between columns by mortise and tenon joints, sometimes also using bundling methods. The columns, tiebeam, and Dou tiebeams are interconnected and combined with earthen walls, bottom plates, and wooden wall surfaces to form the house. (Hand-drawn drawing 1 in Table 2) The upper part above the main penetrating tie on the top floor is usually covered with a ceiling but can be considered as a floor in practice as it is often used as storage space or bedrooms.

The components of the king posts and penetrating ties above the main penetrating ties are very simple, with two shapes: circular and rectangular, without any decoration or carving, and are joined using mortise and tenon joints (Figure 8). The dimensions of the purlins are much smaller than the columns, with a diameter of about 150 millimeters, connected to the king post using dovetail joints and arrayed according to the shape of the two-slope roof. In some earth buildings, there are purlin boards at the eaves purlins, intermediate purlins, and ridged purlins. The method of constructing the eave columns in Nanjing Tulou is quite flexible, with three styles found (Figure 9): the groove in the middle of the upper end of the column supports "Tiaotou" (the end of "Tiao"); the groove on the side of the upper end of the column supports "Tiaotou"; and two columns with grooves on the side of the upper end combine to form a groove in the middle supporting "Tiaotou". (Wu, 2017a) The eave column construction in Tianluokeng Earth Building is based on the single-eave nature of the earth building and adapted from traditional eave column construction (Figure 10), with the base resting on the main through-beam below and supporting "Tiaotou" upwards.

Table 2. Hand-drawn drawings of earth building sections, wood shapes, beam and column structures, etc.

Hand-drawn drawing 1	Hand-drawn drawing 2	Hand-drawn drawing 3	Hand-drawn drawing 4



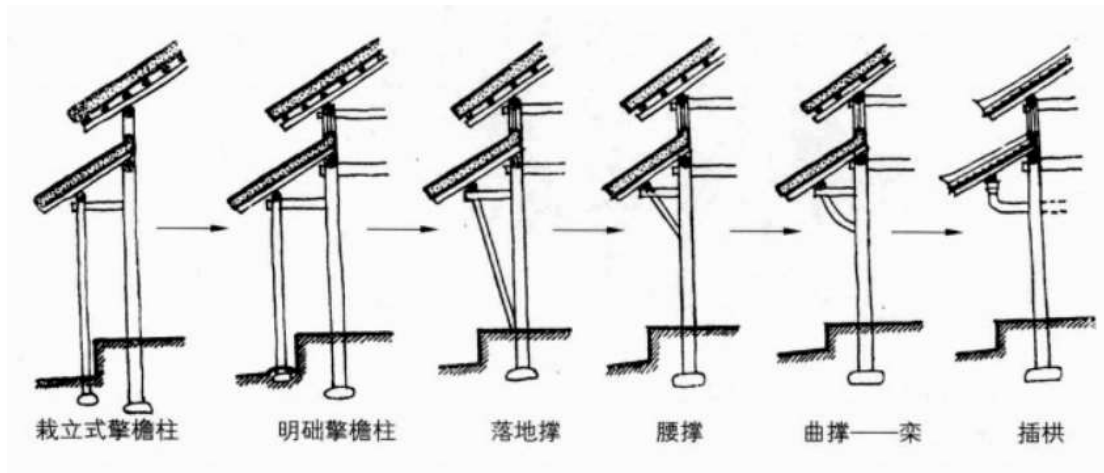
(Wu, 2017b)

Figure 8. Shunyu Building (Shiqiao Village, Shuyang Town) and Cuimei Building (Guanyang Village, Meilin Town)



(Wu, 2017b)

Figure 9. 3 types of ways to connect the eave columns to “Tiaotou”







(Yang, 2008)

Figure 10. The evolution of traditional eaves columns

Small Wooden Structure

Looking at the construction features of the doors in Nanjing Tulou, they utilize a variety of practices from traditional Chinese small woodwork systems for doors and windows, including plank doors, checkerboard doors, partitioned doors, and straight lattice windows. Specifically, in terms of division, it draws from the method of partitioned doors (ranging from two-partition to six-partition doors), yet without the common partition core in the door, instead using plank or checkerboard doors as a replacement (i.e., switching to a plank form), and employing straight lattice windows in the middle (i.e., using vertically divided wooden bars for straight lattice windows). The plank door part can be directly joined between planks or joined using dragon and phoenix tenons, combined with techniques like edge bundling or slotting for panel installation. The straight lattice window part uses square timber in a T-shape combined with mortise and tenon joints, large frame shoulders (false shoulder tenons), and square timber T-combinations (mortise and tenon with larger entry and smaller exit) (Table 3).

Table 3. Mortise and tenon structure commonly used in small wooden structures.

			
Edge bundling and grooving panel installation	Edge bundling and leather corner	Combination of square timbers in a T-shape Large shoulder tenons for mortise and tenon joints	Combination of square timbers in a T-shape (Mortise and tenon with larger entry and smaller exit)

The mortise and tenon structure of the windows in the earth buildings is the same as that of the doors, only differing in the proportion of straight lattice window forms or plank forms. Fences are divided into two types according to their form: one is plank style, and the other is straight lattice style. For the plank style, small wooden planks are first joined together with dragon and phoenix tenons to form a large template, which is then assembled using edge bundling and corner joining. The straight lattice form features the mortise and tenon technique characteristic of square timber T-joint combinations (with a larger entry and smaller exit for the tenon). From this, it can be seen that the small woodwork structure of the Nanjing Tulou is relatively simple and rustic, reflecting on one hand the simplicity of the local customs, and on the other hand, the reverence for nature inherent in its design.

CONCLUSION

The overall characteristics of the Nanjing Tulou utilize local soil and materials, with a simple, practical, durable structure that can effectively resist natural disasters. At the same time, it preserves the unique cultural and historical features of the Nanjing Tulou area, making it a unique example of Chinese architecture. In terms of materials, Nanjing Tulou mostly uses locally available materials, which exhibit a rustic and rough texture. Structurally, Nanjing Tulou still employs traditional Chinese wooden structural systems, characterized by the use of mortise and tenon joints, which demonstrate the architectural construction's character and vary in character due to different connection methods. In future research, further exploration of architectural features and spatial layouts can be strengthened to uncover symbolic and abstract concepts (such as feng shui) for further study.

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