

TULOUP: THE RAMMED EARTH DWELLINGS OF FUJIAN (CHINA). FUNCTIONAL, TYPOLOGICAL AND CONSTRUCTIVE FEATURES

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ABSTRACT:

This research is focused on different aspects concerning two types of Tulou: Minnan and Hakka Tulou. Through the analysis of eight case studies, we managed to highlight the relation between typological-functional features and constructive ones aiming to offer a more orderly analysis of distinct models, divided into two substantially different families. Future studies will further analyse the knowledge of these rammed earth buildings by studying the phases of the construction site, conducting architectural surveys on the most important details and investigating the mechanical behaviour of both types. The future goal is the creation of a “Manuale del recupero dei Tulou” (Manual on Tulou restoration) in order to provide a guide for restoration and spread the knowledge about original materials and techniques applied in the construction of these unique rammed earth architectures. The research, which is currently ongoing, has been carried out by the Architecture Department of Roma Tre University in cooperation with Fuzhou University.

1. INTRODUCTION: MINNAN AND HAKKA TULOUP

Often assembled in small settlements, Tulou are traditional rural architectures built in southern Fujian between XIV and XX century (Figure 1). Nowadays, approximately 3000 Tulou are still standing, among which 45 were recently added to the UNESCO World Heritage List¹. As the etymology of the word suggests (*tǔ* “土” «earth» e *lóu* “楼” «multi-storey house»), the term “Tulou” typically refers to collective dwellings built with rammed earth and wood. Despite the obvious differences in size between different Tulou (the smallest ones cover an area of about 500 square meters, while the bigger ones can reach 4.000/5.000 square meters) and in shape (they can take a round, oval, square or mixtilinear shape), they share a similar design and layout features. Tulou are enclosed buildings, usually three to four stories, clearly built with defensive purposes²: the external, protective wall is always built of rammed earth, with few openings on the top stories and a single monumental entrance; the interior is divided into identical, serial housing units that develop vertically with overlapping single rooms, each with a different function (kitchen, storage, sleeping area).

All Tulou have wooden floors and distribution elements, a hip and-gable roof, a large central courtyard, an ancestral common area and in some cases other communal areas, such as granaries, schools, guest rooms, etc. However, despite the obvious uniformity, substantial differences emerge through the observation of a significant number of cases. For example, some Tulou present an empty courtyard, while others have it obstructed by various constructions (Figure 2).

In some cases, the single housing units are separated by rammed earth load-bearing walls, in others by wooden framework with adobe partitions. Such diversity cannot be disregarded and it is possible to analyse it in detail distinguishing two large families of Tulou: those typically built by Minnan population (i.e., literally, «people of southern Fujian») and those belonging to Hakka population («the guests»)³. Both the non-specialized and scientific literature only incidentally highlight this difference, although it appears to be essential.



Figure 1. Tianluokeng settlement, Yongding County.

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¹ (Zheng et al., 2008).

² Most of the Chinese words using the ideogram “土” (“earth”) allude to a defensive character and refer to the first military structures made of raw earth (Benevolo, 1989).

³ Minnan are also known as Fulao. Both populations (Minnan and Hakka) descend from the Han people, originally from the central plains of the Yellow River in northern China. Due to severe famine and constant

fighting with the Mongols, the Han began to migrate to south China at the beginning of the IV century and reached Fujian district around the X century. The ethnic subgroups – which were responsible for the construction of the Tulou – migrated to this territory via two different routes: Minnan migrated from the southern coast and settled on the estuary of the main waterways; Hakka crossed the Wuyi Mountains and settled along the river valleys (Bielenstein, 1959; Knapp, 2000; Zhou, 2015).



Figure 2. On the left, case study Long Jian Lou, 1662-1722, Pingue County (Minnan Tulou, unit type); on the right, case study Chengqi Lou, 1628-1644, Gaobei settlement, Yongding County (Hakka Tulou, gallery type).

Still today Tulou are generically referred to as *Earthen Round Hakka Building* and most of the research carried out on the subject prefers specific aspects (such as, for example, technological and structural features⁴), historical-descriptive analysis and a chronological or formal cataloguing of these buildings⁵.

Even architect Hanmin Huang, the most revered expert on Tulou, he who first introduced the study of Minnan buildings in 1988, which was previously completely neglected⁶, mainly focuses his analysis on functional differences, only sporadically mentioning the differences in construction methods.

In this study we suggest a systematic approach that, based on this new assumption, analyses the functional characteristics of both Minnan and Hakka Tulou (Figures 4 and 5), and subsequently puts them in relation to the substantial typological and constructive differences, specific to the two families of buildings.

⁴ As regards structural issues, with focus on anti-seismic behaviour see (Briseghella et al., 2019).

⁵ Tulou's most extensive cataloguing is attributed to the studies of Huang, who – in his most recent monograph – classifies them by shape and sorts them according to the exceptional character of individual models (Huang, 2009). In his studies, he also analyses some specific aspects (defensive, constructive and stylistic-decorative, related to the philosophy of Feng Shui, etc.). Please note that only in ch. 2 Huang suggests a subdivision between buildings built by Minnan and those built by Hakka. Another research proposing a case study is the work by Greco (Greco, 2003), in which, however, no specific principle of categorization is mentioned; furthermore we have the paper for the nomination of the Tulou as a World Heritage Site (Zheng et al., 2008), where, in accordance with the aims of the study, the earth buildings are classified according to their state of conservation, integrity and patrimonial value, and are listed by settlement, according to a chronological order.

⁶ Huang's thesis of 1982 published in 1984 (Huang, 1984a, 1984b), ignored the existence of the Tulou type typically attributable to Minnan. It was only after his inspections, conducted together with Zeng Wuyuan, director of the Cultural Relics Office in Zhangzhou, that Huang studied and published for the first time two examples belonging to the "people of southern Fujian" such as Er Yi Lou, in Hua'an District, and Shu Zi Lou in Yunxiao District (Huang, 1988).

2. FUNCTIONAL FEATURE AND TYPOLOGIC ANALYSIS

Through a general investigation of the best known examples in the literature and a systematic analysis of eight case studies with circular layout (four Minnan Tulou and as many of the Hakka's, figures 4 and 5)⁷, it was possible to highlight the main differences from a functional standpoint, which were already revealed by previous studies⁸.

In Minnan buildings, each unit is independent, with a separate entryway and private staircase inside the accommodation. On the contrary, the vertical distribution in Hakka buildings, is coordinated via shared stairs (usually two or four, symmetrically distributed in relation to the rammed earth outer wall) serving common corridors. The corridors on each floor provide access to the individual rooms of private homes.

⁷ The study has compared four pairs of Minnan and Hakka models, grouped by size. Minnan Tulou: *Zhong Qing Lou*, 1950, Pingue County; *Shuzi Lou*, 1789, Yunxiao County; *Er Yi Lou*, 1740, Dadi settlement, Hua'an County; *Long Jian Lou*, 1662-1722, Pingue County. Hakka Tulou: *He Xing Lou*, 1943, Yongding County; *Zhenfu Lou*, 1913, Yongding County; *Zhencheng Lou*, 1912, Hongkeng settlement, Yongding County; *Chengqi Lou*, 1628-1644, Gaobei settlement, Yongding County. For further information on all the models analysed, see E. Colafranceschi's thesis, *Typologies and spatial design of the Fujian Tulou. Historical analysis and enhancement of the earthen architecture*, a.y. 2018/19, supervisors: E. Pallottino, P. Porretta; co-supervisors: C. Nuti, (Roma Tre) and B. Briseghella, (College of Civil Engineering at Fuzhou University, China). Note that not all the selected case studies are included in the UNESCO World Heritage list because, generally speaking, the latter are the ones that have been most recently transformed.

⁸ The analyses that most clearly address this aspect are Huang's studies and the paper for the nomination of Tulou as a UNESCO World Heritage Site (see also, in general, for the most up-to-date bibliographical references). Note that the differences between the Minnan and Hakka Tulou can be found in most cases, however, Huang admits the possibility of structures typically built by one population but inhabited by the other (Huang, 2009).



Figure 3. On the left, a Minnan Tulou with rammed earth load-bearing walls and wooden beams; on the right, a Hakka Tulou with wooden frameworks (2018, picture taken by E. Colafranceschi).

The simple observation of the relationship between accommodation and distribution displays a substantial difference between the two Tulou families: Minnan houses are arranged into *unit type*, which reveals their underlying private nature and can loosely compare, from a typological perspective, to row housing; while others can be defined as *gallery type* or *with corridor*. Despite the same overall size of the structure, the houses of the «people of southern Fujian» also develop a considerably larger surface area and can therefore accommodate more functions within them, unlike the other, smaller ones. In fact, all Tulou have a shared ancestral hall, but only the Minnan houses have a private one (usually on the top floor) and an exclusive courtyard (on the ground floor), in addition to the central common one.

Even the defensive system, placed at the height of the crowning, is radically different: in one case (Minnan Tulou) it is inside the perimeter and configured as a continuous gallery that can be accessed from the individual housing units, while in the other (Hakka Tulou), it is necessarily extrados on the outer rammed earth wall. In fact, in Hakka Tulou there are usually sighting balconies placed in correspondence with the common staircases, probably in order not to further reduce the already limited living space of the rooms of the top floor.

The greater privatisation of functions in the Minnan Tulou also radically affects the configuration of the central court, which remains substantially open, while in Hakka Tulou is often progressively saturated by the addition of concentric building rings, hosting the common areas (warehouses, guest houses, etc., Figure 2)⁹.

In conclusion, the functional and typological features observed (Figures 4 and 5) allow us to highlight a fundamental difference that reflects a different living culture: Hakka Tulou are real *collective dwellings*, with shared spaces and distribution, while Minnan ones are *aggregate private houses*, organised around a common courtyard.

⁹ This structure is noted in most cases, however some Tulou of small size, with a simplified structure, do not include other shared functions besides the ancestral hall.

3. STRUCTURAL FEATURES

The functional and typological traits are never organically associated with the constructive solutions that are quite different in the two families of Tulou.

In Hakka buildings, the radial inner structure leaning against the rammed earth outer wall is composed of a wooden framework (beams and pillars), with adobe partitions between the various rooms. In Minnan Tulou, on the other hand, the housing units are separated by radial rammed earth load-bearing walls with wooden beams and floors (Figures 3, 6 and 7).

This different constructive choice is inextricably linked to the typological structure and influences many aspects, from the size of individual units (width and depth) and that of the building structures as a whole.

In the Hakka type, the depth of the room is necessarily measured on the maximum length that can be reached by the radial load-bearing wooden beams, both those that are directly connected to the pillars and those that lay on the transfer (circumferential) beams and then continue cantilevered to create the corridor (altogether about 4-6 m).

In the Minnan type, instead, the depth of the house is not conditioned by the structure, as the load-bearing walls theoretically have no limits of linear development, but rather by other requirements such as lighting and natural ventilation, among others.

There is no coincidence in the fact—that in Minnan houses usually have a private courtyard on the ground floor, precisely where the depth of building reaches a considerable development.

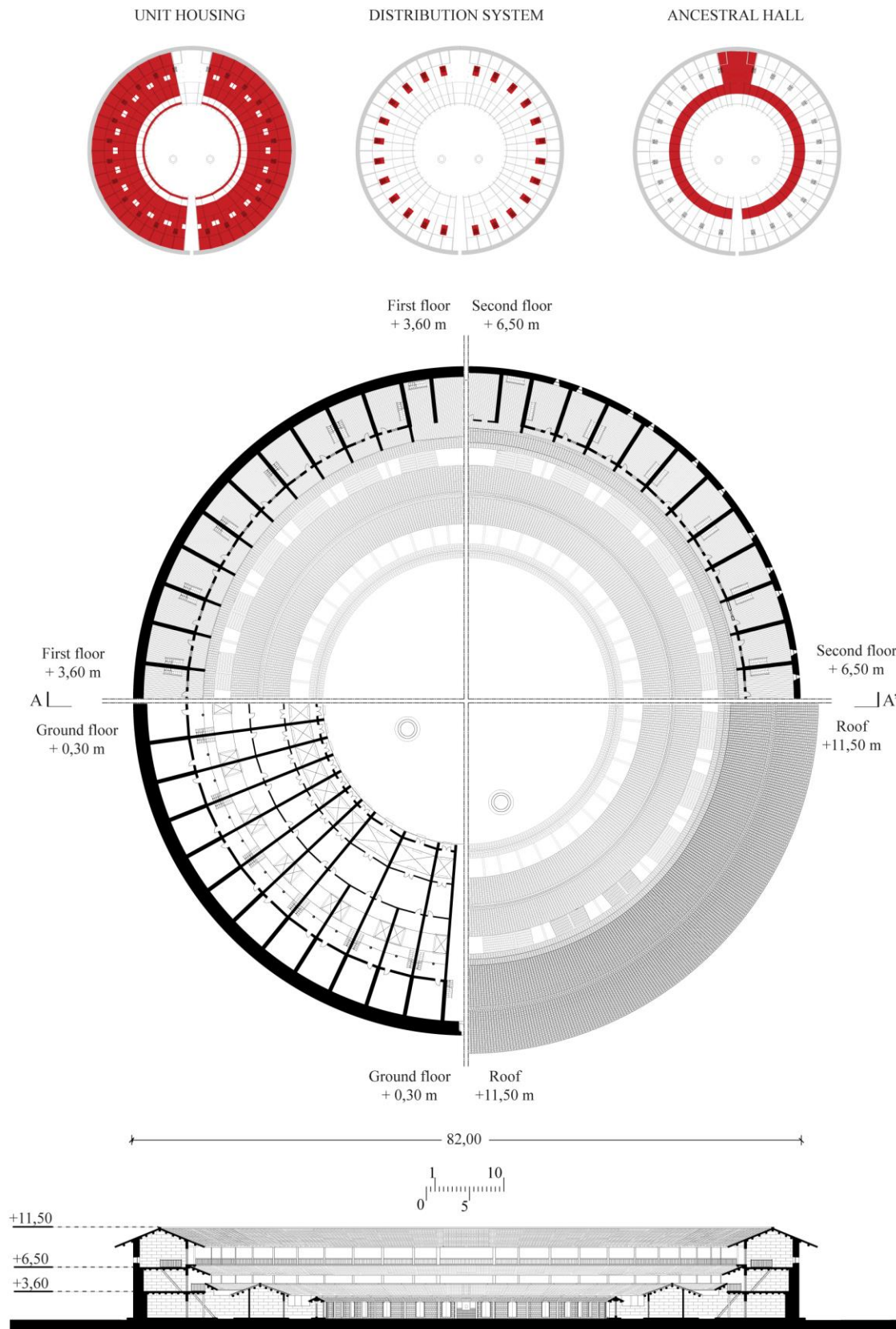


Figure 4. Case study Long Jian Lou, 1662-1722, Pingue County (Minnan Tulou, unit type).

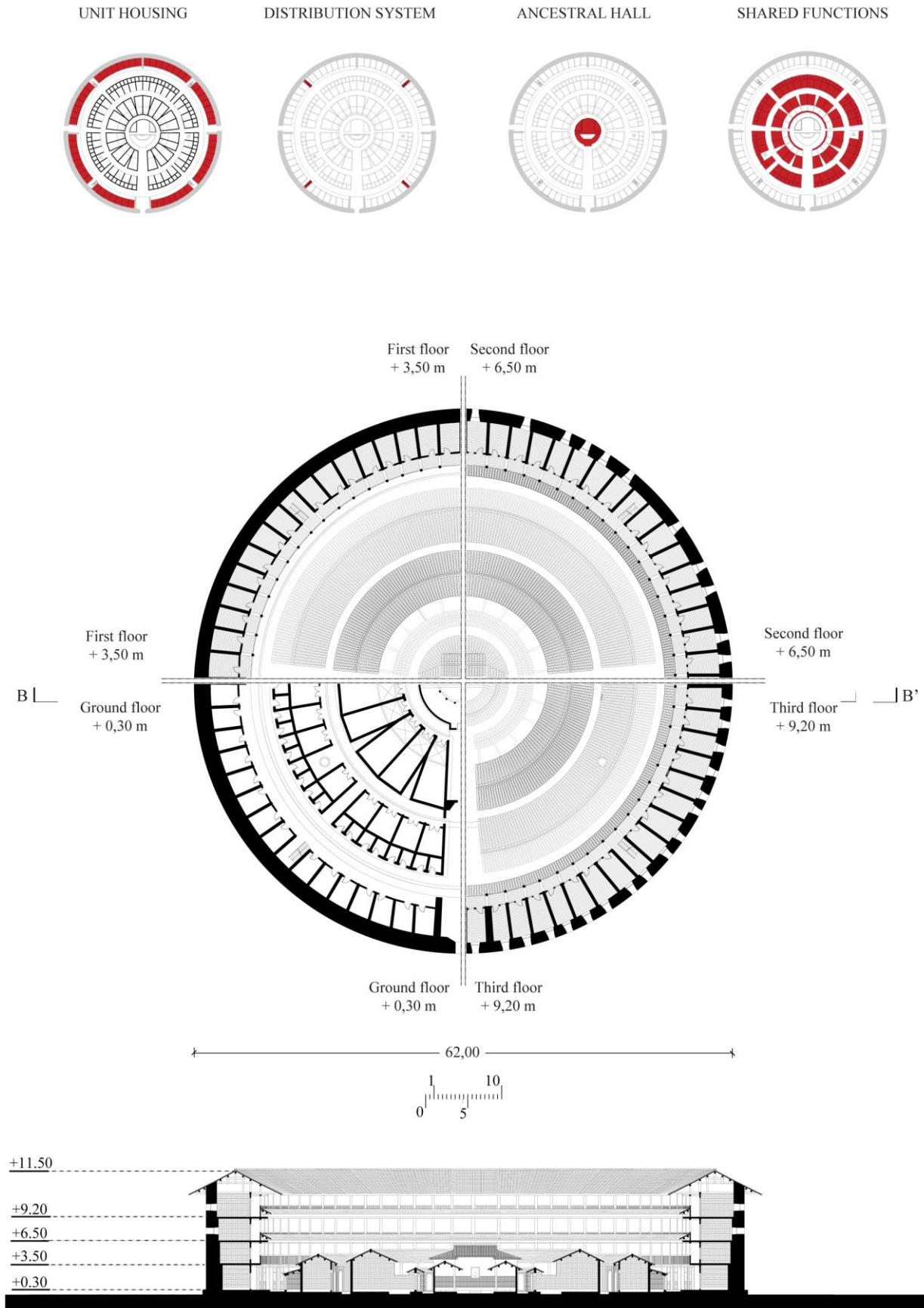


Figure 5. Case study Chengqi Lou, 1628-1644, Gaobei settlement, Yongding County (Hakka Tulou, gallery type)



Figure 6. Study scale model: above, case study He Xing Lou, 1943, Yongding County (Hakka Tulou, gallery type); below, case study Er Yi Lou, 1740, Dadi settlement, Hua'an County (Minnan Tulou, unit type).

It is clear from the analysis of the circular Tulou that the constructive approach – together with with planimetric shape – affects the nature of the central courtyard. As mentioned, in the Tulou of the «people of southern Fujian» the linear development of the rammed earth walls is not limited by constructive requirements; however, the radial arrangement limits their extension for purely functional reasons. In fact, if one imagines extending the walls to the centre of the common courtyard, the distance between them would tend to zero and the resulting space would not be habitable. In the «guests'» buildings, on the other hand, the inner ring – measured on the length of the radial beam – can be replicated in a concentric sequence until the inner rings completely obstruct the central space. As mentioned in the previous paragraph, this condition is related to functional and typological choices, strictly linked to a different living culture, but also, it's made possible by the peculiar structure built by Hakka (Figures 3, 6 and 7). The width of the house is almost always corresponding to the structural rhythm¹⁰ and is locally influenced in both cases by the loads of the floor that circumferential beams must support (note that all the structures analysed in the present study have approximately the same height of about 0,15/0,20 m).

¹⁰ In some cases, as for example in *Er Yi Lou* Tulou, which was subject of the investigation in this research, the structural rhythm does not correspond to the width of the house, which is in fact composed, on each floor, of several rooms defined by a series of radial load-bearing walls.

¹¹ Particle size analysis were carried out through sieving and sedimentation processes on several raw earth samples: five samples taken from the outer walls of several Tulou and three samples of

In Hakka Tulou, the element connecting the pillars is subjected to high stress due to the intermediate radial beams placed on it to support the plank floor. In Minnan Tulou, the circumferential beams, which distribute the load of the floor, go from a load-bearing wall to another and are marked by a regular structural rhythm pitch. The longest beam is also the most stressed one but as well the closest to the large outer wall that contributes in responding to the loads. In a purely qualitative analysis, it seems therefore that Minnan type optimise the mechanical reaction to the stress: in fact, with the same beam cross-section, they must support lower loads and therefore can have a larger span: so it is not a coincidence that the houses of the «people of southern Fujian» are on average wider than those of the «guests» (Figures 6 and 7).

The comparison between different pairs of models also showed that the architectural choices affected the general dimensions of the two Tulou families. Although being the outer wall of approximately the same thickness, the diameter does not exceed 60 meters in the one case, while in the other it can reach up to 80 meters, probably due to a better integration between the outer element and the inner structure – both built in rammed earth – and to a greater overall stiffness resulting from the architectural choices.

4. BUILDING MATERIAL: RAMMED EARTH AND WOOD

Tulou building tradition is based on the use of local building materials: rammed earth, stone and wood. The outer wall is constructed using the rammed earth technique (*pisè*): a building process involving the compression and compaction of the earth inside wooden movable formworks (approximately H. 0,40 m, L. 1,50/2,00 m).

The mixture used is called *sanhetu* and is composed of silt, sand and clay as binding agent¹¹. The wall is made of modular blocks, called *ban*, arranged in horizontal layers and separated by a layer of *shānmù* bark to create the laying surface and prevent moisture from rising. Inside each *ban*, longitudinal bars made of bamboo reeds and *shānmù* branches are inserted. In order to protect the structure from rainwater, the raw earth wall is placed on a large foundation made of dry-stone masonry with pebbles. As has been pointed out, the partitions of the inner structure vary according to the type.

The housing units in Minnan buildings are separated by load-bearing pie walls, while in Hakka buildings the housing units are marked by wooden framework and non-load bearing adobe partition (Figures 6 and 7). The adobe preparation involves the use of a mixture of earth mixed with vegetables fibres and poured into wooden formworks which determine the size of the brick to be produced.

As per Tulou, these are one-headed brick walls (H. 0,15 m, W. 0,30 m, D. 0,15 m). Inside the Tulou, all floors and beams are always made of wood with jointed without the use of nails and iron elements, consistently with the general Chinese building tradition.

Tubao. Located in Fujian district since the X century, the latter buildings have an exclusively military function (Dai, 2011). A specific ongoing study suggests a possible typological evolution, according to which the residential function could have been progressively integrated with the exclusively defensive function of Tubao.

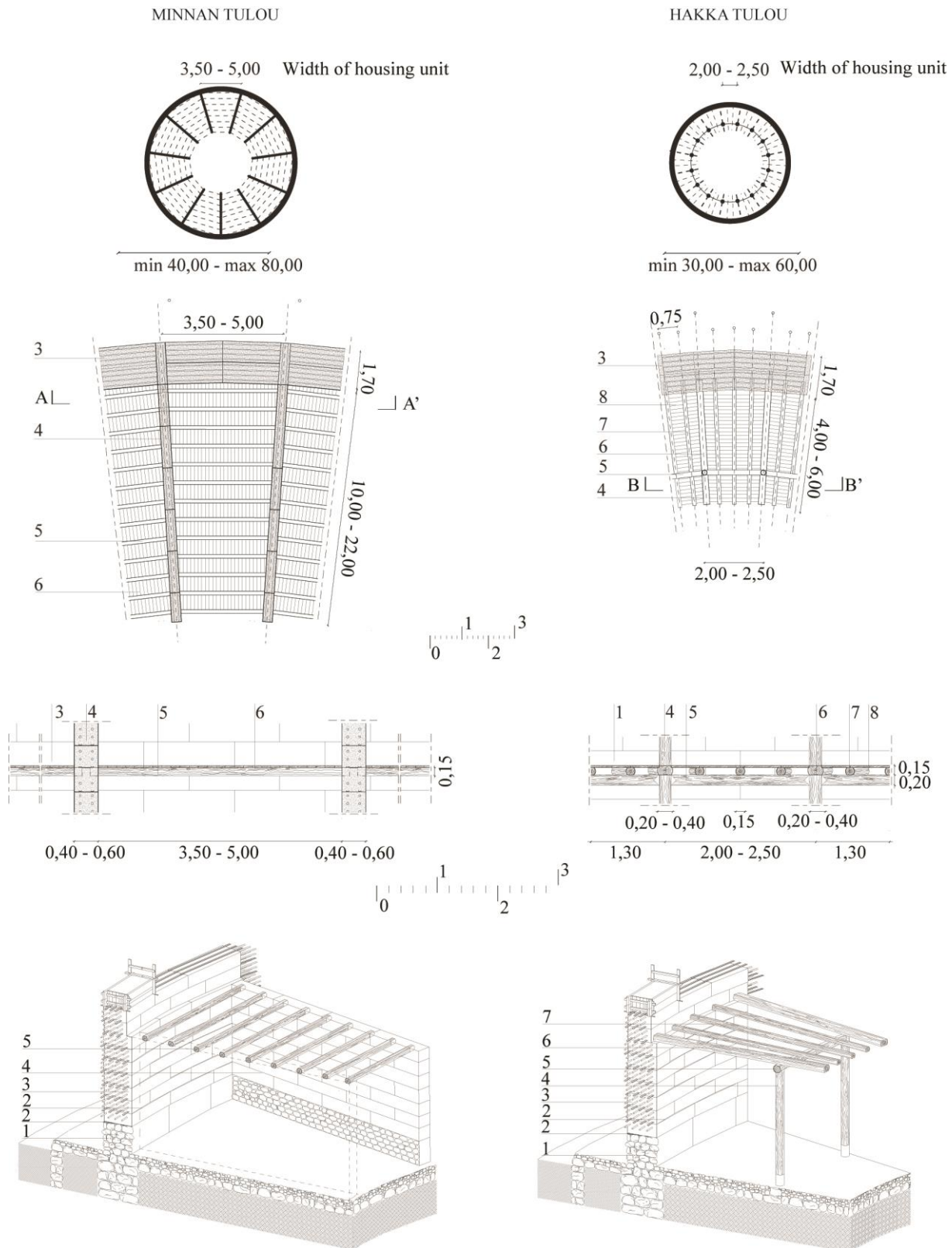


Figure 7. Constructive systems. On the left, Minnan type with rammed earth load-bearing walls and wooden circumferential beams (shānmù): 1. foundation and base in roundish river stone or, in rare cases, in chippings obtained from quarry crushing; 2. layer of bark to level the laying surface and to prevent moisture from rising; 3. rammed earth outer wall made of horizontal rows (wooden formworks H. 0.40, L. 1.50/2.00 approx.) with the insertion of bamboo reeds and shānmù branches in the mixture; 4. radial rammed earth load-bearing walls; 5. circumferential beams embedded in the rammed earth load-bearing walls; 6. plank floor. On the right, Hakka type with wooden frameworks (shānmù): 1-2-3. as per previous legend; 4. pillars with circular cross-section and stone base; 5. transfer (circumferential) beam, with shaped section, embedded between the pillars; 6. radial beams, with shaped section, in correspondence with vertical supports; 7. radial beams, with shaped cross-section, placed on the transfer beam (5); 8. plank floor.

The wood used is called shānmù which is literally equivalent to the Chinese fir. However, due to its characteristics, this essence can be compared to the family of redwoods or Japanese cryptomeria and is therefore more properly assimilated to cypress.

CONCLUSION

The scientific and cultural interest in these earth buildings located in Fujian began to arise in the middle of the last century; just a few decades after that, the construction of new Tulou ceased definitively. Many «earth houses» are still inhabited nowadays, but many are in progressive abandonment and in an evident state of decay. Through its recent recognition, UNESCO has sanctioned the value of these architectures but, at the same time, it has also triggered a delicate process of tourist fruition and musealization in relation to both the material and immaterial culture of Tulou. Improper technological adaptations, structural consolidations inconsistent with the ancient building tradition and incongruous additions are recorded in several cases, but it is precisely the buildings included in the World Heritage List that have already suffered the most damage: re-functionalization and partial changes of use have transformed kitchens into shops, entire Tulou into hotels or museums, where rammed earth walls and adobe partitions were improperly plastered, courtyards were inappropriately buffered ceilings wrongly built. Furthermore, in the name of promotion, the surrounding landscape has undergone equally worrying transformations, with new access roads and decorative elements appearing that are completely unrelated to the original landscape, which Tulou have been an integral part of for centuries.

Planning conscious restoration, recovery and maintenance projects seems more urgent than ever today. Many studies are ongoing, and many are still to be launched (i.e. specific studies aiming to analyse the agricultural and productive aspects of the landscape in addition to the ones concentrating on the natural landscape, as most studies do).

Italy has experienced problems with the conservation of “minor” traditional architectures were experienced long before those of China. These experiences have shown that maintaining the original structures, respecting the different constructive and typological characteristics, using techniques and materials linked to tradition is often the best response to any type of intervention, even when the buildings of the past have to be modified for different uses, updated to new living conditions, consolidated after natural disasters. It is precisely in this direction that the Department of Architecture of Roma Tre University, in collaboration with Fuzhou University, intends to work. The study conducted so far¹², which is still in progress, has directly linked the features of the living culture, the typological-functional structure and the main constructive characters, proposing a more organised analysis of the different models, divided into two substantially different families. Starting from this approach, future research will have to deepen the knowledge of the materials, study the original construction site, conduct architectural surveys on the main constructive details, investigate the mechanical behaviour of the two different types, with the aim of publishing a “Manuale del recupero dei Tulou” (Manual on Tulou restoration) intended – consistently with the consolidated tradition of these studies – as a tool for deepening and spreading knowledge and as an operational guide for the maintenance and restoration of these extraordinary architectures.

¹² The study here presented is the first result of an ongoing research conducted by the Department of Architecture of Roma Tre University (E. Pallottino and P. Porretta, scientific directors, E. Colafranceschi,

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