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PALAFITAS & TULOUS: A COMPARATIVE ANALYSIS OF THE CLIMATIC RESPONSE FROM THE VERNACULAR ARCHITECTURE OF FUJIAN (CHINA) AND AMAZONAS (BRAZIL)

PALAFITAS Y TULOUS: UN ANÁLISIS COMPARADO SOBRE LAS RESPUESTAS CLIMÁTICAS DE LA ARQUITECTURA VERNÁCULA EN FUJIAN (CHINA) Y AMAZONAS (BRASIL).

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AbstRAct: This paper presents a comparative climatic analysis response of traditional dwellings in two locations: Northern Brazil (Amazon) and Southern China (Fujian). The study explores how positive and negative aspects of traditional dwellings (Construction/ materials use) need to be addressed at a larger scale, across diverse communities, if it is to survive the tests of practicality, convenience and environmental feasibility within our modernized and urbanized world. Vernacular architecture, despite its widespread acceptance amongst academics, and increased interest by high socio-economic layers of society, especially in the developed world, is in fact on a decline within local rural traditional communities. The three key reasons for such decline are based on: high maintenance costs (especially labour), poor overall performance of traditional buildings, followed by associations of poverty with locally sourced materials. The need for better understanding of the needs and aspirations of diverse communities and their living conditions, can lead us towards architectural solutions that are affordable, environmentally appropriate

and engaging of traditional and contemporary approaches towards buildings. This particular study focuses on the analysis and response of roofs, given its significance as a construction element that provides not only shelter, but structural integrity for traditional dwellings.

Keywords: vernacular architecture; warm-humid climates; modernity; environmental design

Resumen: Este artículo presenta un análisis comparado sobre las respuestas climáticas de viviendas tradicionales en dos regiones: el norte de Brasil (Amazonas) y el sur de China (Fujian). El estudio explora la forma en que deben ser encarados a gran escala los aspectos positivos y negativos (en cuanto a la construcción, los materiales y demás) en pos de superar los desafíos de la viabilidad, conveniencia y factibilidad ambiental en un mundo moderno y urbano. El uso de la arquitectura vernácula ha disminuido en las comunidades rurales tradicionales, a pesar de la aceptación generalizada entre los especialistas y del interés de las capas sociales más altas. Es posible señalar tres elementos claves de dicha disminución: los altos costos de mantenimiento (especialmente laborales), bajo rendimiento general de este tipo de construcciones, seguidos de la asociación entre pobreza y materiales de origen local. La búsqueda de una mayor comprensión de las necesidades y aspiraciones de diferentes comunidades y sus condiciones de vida nos puede guiar hacia soluciones arquitectónicas que sean asequibles, comprometidas ambientalmente y centradas en formas de construcción tradicionales y contemporáneas. El presente estudio se centra en el análisis de los techos por su significación como un elemento de construcción que provee no solo reparo sino también integridad estructural para viviendas tradicionales.

Palabras clave: arquitectura vernácula; climas cálido-húmedos; modernidad; diseño ambiental.

I. Introduction

Roofs are the most significant feature of dwellings, particularly traditional dwellings as these are a response to cultural, environmental and social contexts. The reason for such critical role of roofs in buildings it is because it not only provides shelter, but it also ensures structural integrity and protection. Roofs represent the largest component of costs of any small building. It combines a number of technical problems and solutions, dominating normally the appearance of any traditional construction in particular. Given its high visibility and area, it has been common that roof coverings in traditional dwellings have used a diverse range of materials, available locally, such as grasses, straw, heather, bamboo, branches, timber, logs, wooden boards, shingles, tiles, sod, mud, stone and the list goes on. However, the vanishing

of traditional practices, and the use of manufactured and processed materials sourced outside communities, are a result of a search for convenience, practicality and modernity. Other studies (Li *et al.*, 2013), (Nelson, 2010) have mapped extensively the impact of such transitions with relevance to resources, increasing inequalities and low quality of life and well-being. This study aims towards a comparative analysis of two very different cultural contexts (China/Brazil) and very different local architectural typologies (earth tulous/timber palafitas) in terms of its climatic and resourceful responses to its context. The important similarities within these two locations and typologies are not directly formal but processual event though at particular seasons, the way in which the architecture responds has many similarities. Any vernacular architecture aims towards integration with its immediate environment, through the application and the use of simple construction materials which are sourced locally, enable the promotion of spatial distribution that tend to allow for good levels of thermal comfort as well as social engagement. It seems to match the search for what we call a sustainable environment.

Because it is an older architectural language, many of the concepts applied by the vernacular architecture are deprived from any industrialized patterns or processes, such as acclimatization systems or electrical lighting. It's an architecture of the basics/essentials, but that delivers with adaptability by the users, an architecture connected to its context, environment and inhabitants. It is therefore, a basic foundational model worth of studies given its uniqueness of responses, quality and performance of spaces.

This study presents particular traditional housing typologies within Northern Brazil (Palafitas in Amazonas) and Southern China (Tulous in Fujian). The increased importance of studies on vernacular architecture during the last decades have been born out of interdisciplinary academic fields, such as anthropology focusing on diversity and cultural identity studies. Over the last two decades, architects and engineers have further engaged on qualitative and quantitative studies of building materials and structures, allowing tests to be conducted, improving building standards and materials specifications to provide more opportunities for improving performance and building with traditional materials in rural and urban areas. This expanded perspective that we have today on traditional materials has brought understanding and a considerable acceptance amongst academics of vernacular architecture. However, despite such increased interest by high socio-economic layers of society, especially in the developed world, there has been a declined interest within local rural traditional communities. The key reasons for such decline are based on: 1) high maintenance costs – both in terms of resources and time/craft-labor of traditional buildings; 2) lack of local knowledge and efficient ways to conquer structural and material failures/maintenance and performance; 3) followed by associations of poverty with locally sourced

materials. It is likely that as societies are shifting towards solutions in urbanized centers that should be affordable, environmentally appropriate, diverse and engaging of traditional and contemporary approaches towards buildings, there will be more importance on learning from the contexts of vernacular architecture and their communities. The need for better understanding of socially and cultural diverse communities and their living conditions, can lead us towards architectural solutions that perform well at the different scales and needs of contemporary societies. This need for grasping the essence of what vernacular architecture means with its invisible qualities (e.g. performance), and avoid the collage of external appearances, is explicitly expressed on this ancient Chinese poem, as cited in Wang (2012):

“Play not music of past dynasties: sing instead the revised song of willow twigs”.

The rapid changes our societies are going through demand solutions that are based on developments that is supportive of convenience and modernity but non-threatening to our Earth’s life systems. The key to such advancement lies on a balance between scientific and technological advancement, and a thorough understanding of human needs and solutions, as culturally appropriate in a global context. The understanding that there are limits to our wants and that our needs should be provided within certain parameters and contexts. Such levels of development require what Rees (2011, 2014) and Nelson (2012) describe as ‘de-growth’, or development decoupled from energy resources as being observed and practices (e.g. some Scandinavian countries).

Depletion of resources, increased inequalities and low quality of living, well-being cannot be decoupled. These are three aspects that developing nations such as China and Brazil (as per vernacular case studies presented here) are facing and vernacular settlements can well advance much knowledge on how to live within our means. There is no advocacy on this paper to return to earlier ways of living or to abandon the possibilities of technology. The opposite is true. The argument lies on simply better understanding the ideas behind an architecture that has survived centuries of settlements, occupations, wars and weather, providing protection and shelter for its inhabitants. To what extent we are able to adapt our contextual and contemporary needs and reinvent what is to come ahead and how, is part of our role into our modern society.

II.1. The Traditional Architecture of the Amazon region (Brazil): ‘The Palafitas’ and ‘the cavaco roof’

‘Ribeirinhos’ are the common name given to the inhabitants of the rural areas in the state of Amazonas, Brazil, along the river beads. They are

grouped in communities, and given their isolation from each other, (where areas are mostly accessed by boat or plane throughout the year), these areas are called 'varzeas'. It is named so, because these particular areas of forest, are seasonally inundated, and this prompts the inhabitants of the river beads (the Ribeirinhos) to establish themselves in such locations, searching for better access to food and transport according to the higher or lower levels of flooded areas (in some cases, up to 10m). The housing typology normally found in these areas of forest, are named 'Palafitas' (Figures 1 and 2).



Figures 1 and 2. (Photos of floating home (Photos courtesy by Fernando Pedrosa, Manaus-AM, Brazil)

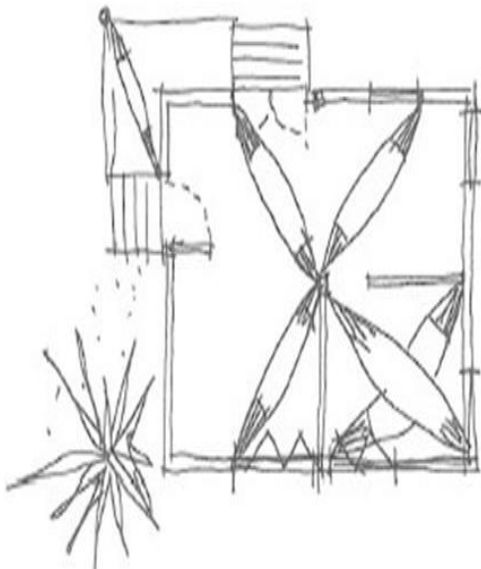


Figure 3. Plan of the Palafitas. Architecture of essentials, hammocks, openings and flexible spaces. (After Machado, Ribas and Oliveira).

Water communities in many areas across the globe tend to use such construction systems, while inhabiting riverbeds. Such vernacular architecture, in which the figure of the architect is not relevant, there is a complete manipulation of environmental resources available, allowing the daily life requirements to be fulfilled by the immediate and extended environment.

II.2. 'Palafitas' and its historical early transitions: 'The Old House' and the Modern House'

The two typologies used by the Ribeirinhos are simple called: the Old House and the Modern House (Figures 3-4). These are very similar to the houses used much earlier by the 'seringueiros', the extractors of rubber in the forest, based in the Amazon region since the 18th century. These two types of houses display connections with the Northeastern houses of Brazil, (as the rubber tree plantation owners were originally from the NE and migrated to the Amazon). We can highlight the main differences from these two houses, and the use of industrialized products as the most relevant. From roofing systems composed of aluminum sheets/structured by treated timber, to diverse range of industrialized materials in the walls and painting. This comes into direct contrast with the basic resources, at its raw form, brought from the forest, that we can find in the Old House typology.



Figure 4. (Left(A) and Right(B) Old Houses. (Photo courtesy: Aquilino



Figures 5 and 6. (Left(A) and Right(B)). Modern Houses (extended terraces, transformed roofs). (Photo courtesy: Fernando Pedrosa).

II.3. Transitional Spaces and Climatic Response

Within the structure of the Ribeirinhos house, there are also temporary spaces, called 'barracoos' which are basically transitional semi-open spaces. These are spaces integrated to the landscape, and allocated for activities during the day or night, considering the harsh climatic conditions (allowing wind breezes/solar protection – Fig 5 demonstrates sun path diagram and bioclimatic chart for Manaus-Amazon, with very high humidity (above 90% and high temperatures). Kitchen and related activities, such as drying of nuts/cashews, spaces for storing and preparing the latex (smoked), and the powder house. The site orientation/direction/form, is a direct reflection of the human needs, the landscape (relationship to the river) the possibility of mobility as well as the hydrological cycles of the area, and the climatic response.

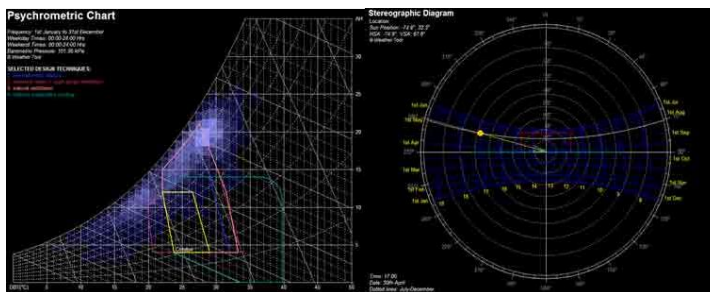


Figure 7. (Left) Sun path diagram; (Right) Bioclimatic chart for Manaus, Amazon-BR.

II.4. Materials choices: the “cavaco roof” and the transitions into modernity

The original materials used for the construction of Ribeirinho houses was primarily wood, in conjunction with straw (palm-trees), as well as the natural ropes, made out of ‘cipo’ (fibres). Nowadays, with the advent of industrialized, more convenient materials, acceptance of such ‘raw’ materials, is vanishing quickly, in favor of more durable, and perceived as less primitive. The Ribeirinhos, as any other rural community nowadays, aspire for modernized = industrialized materials. The three main reasons for such perception rely on:

- A) The desire for a permanent, firm construction. One that suggests eternity (durability). As discussed by Lemos (1999), this desire is associated with the dominant elite’s own aspirations for permanence, a concept very opposite to life in the forest. The indigenous

seminomadic people that have established such typological constructions are therefore perceived as precarious and undermined as a way of living.

- B) Denial of the indigenous and caboclo identity. This is not an isolated attitude in Brazil, even if it's changing in the last few years. In the Amazon region, this is still a very strong deconstruction of the indigenous and the 'caboclo' image. There is this association of these communities being backwards: socially, culturally and economically.

- C) Unsuitable aspects of construction: This is the aspect which technically needs to be verified. The proliferation of insects and fungi in the roofing (when made out of palm-trees) and also as walling system (mosquitoes, and bats); Another aspect is the fireproofing of the materials (DePaula & Tenorio, 2010).

The roof aspect of the Ribeirinhos house is one that shows most relevance. Originally such roofs were either built from straw or cavaco. Both options, when harvested at the forests nearby can last between 12-20 years (Michiles, 2005), but given the pressures towards sustainable management of forests (not necessarily existent within rural areas of the Amazon region), and the appropriate dissemination of oral knowledge (harvesting of traditional resources, which is gradually disappearing), there has been a rapid disappearance of such understanding and techniques of roof construction within the Ribeirinhos housing typologies.

In terms of thermal and in particular acoustics comfort, such change in materials use and design decisions have a direct impact, both qualitative and quantitatively at the performance level, not necessarily as a benefit for the homeowners or the communities. This has been extensively demonstrated in the literature, in particular in regards to thermal comfort studies where temperatures in excess of 7°C higher have been recorded after roof transitions (Shastry *et al.*, 2012). With such increases in discomfort, homeowners would not go back to the traditional solutions to look into improving performance, but would choose towards a path of modernization. The reality is increased energy consumption due to the use of fans and air conditioning even in small rural villages.

As we understand sustainability in buildings and as it is found in the case studies here represented (vernacular dwellings): the aim is to maintain the higher levels of thermal performance, low levels of energy use (both embodied energy and operational energy), increase health levels and improve the recyclability potential of materials. However, the new choices of materials

and construction methods are neglecting such principles, and clearly primarily concerned with the immediate needs of transitions into convenient, short-term affordable construction materials that can provide a modern appearance. It is important to notice that such changes are a reflection of the lifestyle changes in such communities too (e.g. work patterns, lowering of gender gaps, higher levels of education, which in general are signs of progressive ways of living. However, such enhanced quality of living, needs to be expressed also on construction practices that continue to be in harmony with the natural environment, and taking into account the needs and aspirations for modernization of rural communities. The combined impact on visual, thermal and sound comfort of houses, due to the specific changes of roofs, is being documented and further studies that can also explore comparatively the effect on urban comfort and increase on energy use at household level is fundamental to map and develop possible alternatives of materials and construction techniques, and validate standards and legislation to allow for such systems to be implemented.

III.1. The Traditional Architecture of the Fujian Province (China): 'The Tulou' and 'The Xuanshan Roof'

The Tulou Buildings are a differentiated type of rural building (also a Unesco world heritage site), distributed across areas of Southeastern China. Built out of rammed earth and using a wooden structural system, these buildings are mostly built on warm-humid mountainous areas, surrounded by green and dense forests (cypress, pine and camphor), materials which are very favorable for the construction of roofs – Xuanshan (or overhung gable-end roofs), widely used in most traditional dwellings in the area. The buildings we discuss here are the ones found in the particular region within the Fujian province (Figure 8), Southern China. The historical origins and characteristics of these buildings are connected to those of the Song Dynasty curved roof (Wang, 2012). It is a particular interesting case study given the scale of such buildings, and the interconnectivity of the courtyards, with smaller and bigger shapes, contrasting squares and curved patterns, horizontal and vertical constructions, with a combination of earth and timber elements. The word 'Tulou' in Chinese means 'clay buildings', and the main function of such buildings is to house a number of families or clans. Several stories high, these groups of buildings have served as villages, housing up to 800 people (Knapp, 1986).



Figure 8. Tulou buildings/Roof details, Fujian Province. Photos by the author; (Left) External, (Right) Internal

“The clever combination of Xieshan and Xuanshan roofs, the interlacing of courtyards, the scattered placement of roofs and the use of those with nine ridges and large projecting eaves for special effect, create a setting that the brilliance of its artistry must be considered a masterpiece” (Wang, 2012).

The actual value and stature of this architecture has been recognized as Unesco World Heritage, and different from the Ribeirinhos vernacular architecture of the Amazon, previously discussed, it is not a construction system to disappear. But it is not also, a construction type to be replicated within the current context of modernizing, industrializing and urbanizing China. The need to learn from the actual performance of such buildings and the essence of its construction elements and variety of forms, patterns and shapes, aligned with the needs of those that have built these groups of dwellings is paramount since such communal practices are disappearing and becoming simply a site to be visited and cultivated as a memory. In a sense, just like the Ribeirinhos, it is a system of living in complete decline but with much that can be learned from its presence in a country like China that is moving too fast towards industrialization and modernization.

III.2. Climatic analysis and response towards indoor luminous, acoustic and thermal environment

Considering the five Chinese climatic regions, partitioned by the Ministry of Construction P. R. China, the Fujian province is within the ‘Hot Summer and Mild Winter Region’ as per map displayed below (Li *et al.*, 2013) (Figure 9).



Figure 9. Specification for thermal design of civil building GB 50176-93. (Source: www.eoearth.org)

The Tulou buildings demonstrate a very different approach towards control of climate, and responsiveness in a warm-humid climate. Different from the Ribeirinhos architecture, which relies on passive cooling strategies such as solar control and cross ventilation, (lightweight structures), The tulou buildings uses heavyweight construction with much thermal mass and enclosed structures, minimal apertures to avoid direct solar access in summer, while maintaining a stable and pleasant thermal environment in both seasons. It is important to note the climatic differences, and the seasonal variations (summer and winter, even if mild), as well as the microclimatic conditions (mountainous regions) of these locations (Figure 10). These allow for solutions that aim towards avoiding and allowing heat gains in some times of the year/as well as day-night. The use of thermal mass therefore, as discussed in the literature, has proven to be equally effective depending on the type of uses, the operational modes and the ways in which ventilation is provided seasonally and daily (Sun, 2013) (Szokolay & Tenorio, 2002).

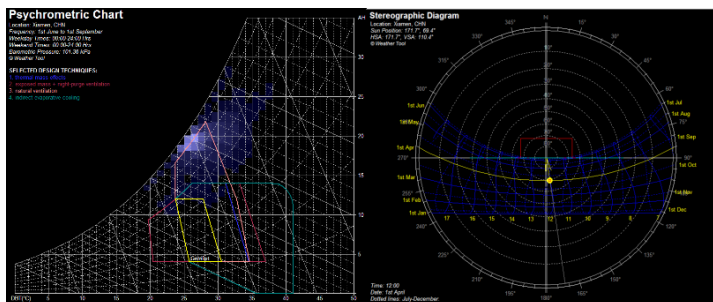


Figure 10. (Left) Sun-Path Diagram; (Right) Bioclimatic chart for Fujian, Xiamen.

Summer cooling is the major issue in terms of indoor thermal environment for the Tulous, as per the case study in the Amazon (Ribeirinhos). But given the extensive use of thermal mass (walls up to 1.5m width), the courtyard formation which facilitates the shading of the walls, and the verticality of the structure with reduced roof area directly impacts on diminished importance of the roof in regard to heat gains. The microclimate created by the construction itself, promotes an actual vertical differentiation on subjective perception of thermal comfort, visual comfort as well as sound comfort throughout these constructions (as per measurements, and extensive studies conducted on site) (Li *et al.*, 2013).

Throughout the field work conducted on site at Fujian Tulous (Nanjing area) in 2014-5 by the author, it was possible to observe three clear patterns:

- A) Patterns of abandonment of Tulous, due to the high costs of maintenance of such buildings, and the lack of labor and knowledge of those left behind, to support such activities. Nowadays due to the high migration into cities, it is common to find only elderly and very young children in rural villages in China. There are thousands of Tulous spanning across different provinces in China, and therefore only a few were declared UNESCO World Heritage. Those outside the UNESCO protected areas are prone to disappear, probably with their aging and migrating population as well as their customs and culture.
- B) Patterns of transformed usage of Tulous. Within the declared protected UNESCO areas, there are a number of Tulous in the vicinities that can be renovated and are in the best possible position to provide the necessary infrastructure for the thousands of tourists that come to visit the Tulous. Such renovated Tulous are new hotels (protected on its form and shape from the outside, but with a whole set of systems and services from the inside. and therefore can support a number of necessary touristic activities. This is an excellent possibility for the survival of such structures, except for the fact that the way in which has been happening does not necessarily fits building codes or standards (e.g. earthquake, fireproof or energy performance standards).
- C) The last pattern of usage of Tulous is nowadays the actual protected sites by UNESCO, in which people come to visit and pay tickets. Such structures are used mostly as markets, and very few inhabitants still live in there today. For those that do live there, it is common knowledge that a number of them also do own a house outside

of the Tulous. This would not be much of a problem, except for the fact that officials seem to want to pass the impression that people still live there, live by the land and for the land and are very happy in those frozen conditions. By talking with locals it was clear that the majority of those owning stalls at the market lived outside, had houses and modern lifestyles, and couldn't quite understand why people wanted to see such old, clay buildings. "Yes, these look very different, but it's old, and it smells... it's difficult to clean, and it's so small, with so many stairs. This is not what I want for my family... besides I don't grow rice anymore, this was for my forefathers. All this field around us, we pay others to do it". There is also much controversy on why only a few of such clusters have been chosen as UNESCO heritage sites, and why specifically the ones chosen were in the list rather than others. We could say however that we are glad that for whatever reason, some have been chosen and these will remain in shape and form, not necessarily in values and practices for the future generations to see.

When one visits the Tulous, there is this clear sense of so many different Chinas living side by side. It is the tension of what will happen when all these villages become empty by this excessive pace of migration and labour change? What will happen to the left-behind children and their elderly parents, will China still be able to preserve their family values after this wave of industrialization? Who will produce food and resources for such urbanized population, where rural people and their practices have become a sign of backwards living; and urban has become the place to be in the 21st century? While western societies are moving towards self-sufficient models, more interconnected models and less hierarchical structures, China seems to be ignoring important lessons right on their backyard of sustainability and progressive environmental living. It will not be by focusing on technology alone, (e.g. by transitioning from coal towards renewable energy technologies which is indeed quite a long way to go for China) that it can declare itself a sustainable country. It will be certainly though a combination of environmental, social and economic strategies that will allow China to move into the 21st century as a world leader. Having money in times of turmoil might not mean much, in view of famine, droughts, natural disasters and alike. The Tulous are a sign of resilience, patience and perseverance of the Chinese people. It is a reminder of resistance of family values versus war and challenges from outsiders, that stand empty today. Ready to offer its lessons to those willing to learn from it.

IV. Conclusions

In this study, a comparative climatic analysis of traditional dwellings in two locations was presented: The Palafitas buildings within the Ribeirinhos communities in the Amazon region of Brazil and the Tulou buildings, within the province of Fujian in China. The paper highlighted the climatic context of these areas and connected to the built response of those traditional communities, considering the use of resources, and the environmental perception in regards to thermal, sound and luminous aspects. The relative influence of roofs in both contexts has proved to be very different, given mostly due to the form-structure/patterns and scale of construction. For the Ribeirinhos, the changes in terms of replacement of materials are affecting negatively the overall environmental performance of such buildings. In the case of the Tulou buildings, such changes are not happening, since these are World Heritage sites. However, the same ‘vanishing’ effect is present, as rural communities are not taking up any of these traditional techniques/systems of construction, due to the search for modernity, industrialization and convenience. Such decline is observed because mostly of the association of rural living with poverty. The phenomenon of mass production and industrialization is clear for both cases, where inhabitants aim towards an appearance of belonging to the industrialized, urbanized world. As discussed on the limitations of this study, further analysis with quantitative data is necessary to determine how these changes also impact on the overall energy consumption of these buildings, and how this can effectively represent a threat to this new society that is being created. These can be important data on scanning the potential for providing housing and construction systems that truly contributes towards a modern world, that values both traditional architecture and contemporary livelihoods, with new aspirations and forms of living taking into account the existing traditional solutions and aiming towards its reinterpretation to support new lifestyles and natural resources.

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