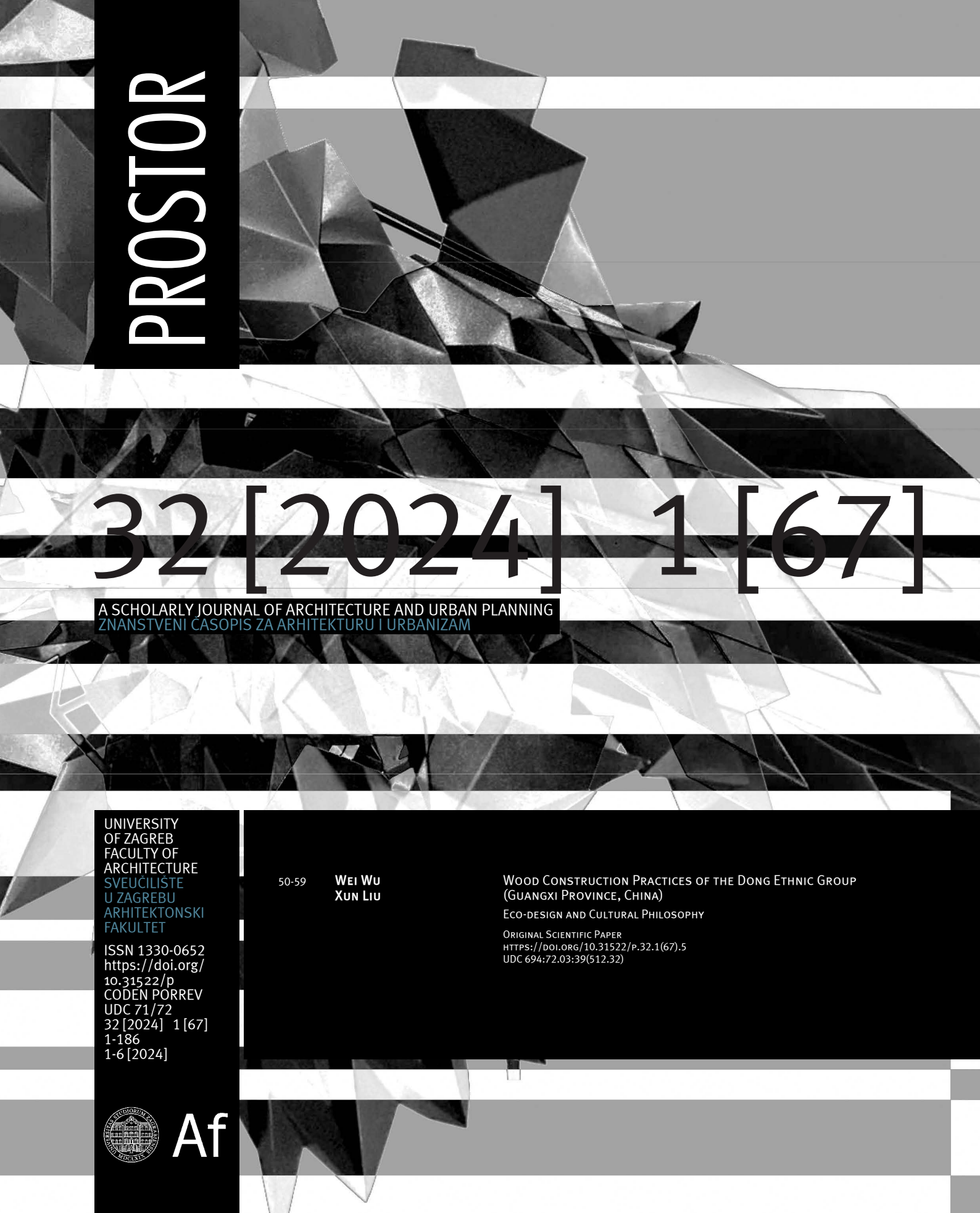

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Fig. 1 Guangxi province, view on the traditional Dong settlement

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Wood Construction Practices of the Dong Ethnic Group (Guangxi Province, China)

Eco-design and Cultural Philosophy

building sustainability
Dong eco-design
house construction
resource usage optimization
wooden architecture

This exploratory multiple-case study aims to analyse the ecological design of wooden houses in Dong villages (Guangxi province, China). Residential and public Dong houses were investigated from ecological and cultural perspectives. The results show that topography (i.e., building near the river in a mountainous area) is the main factor influencing the Dong building construction process. It also affects the building layout decisions. The life cycle assessment was applied to collect general information about the exterior and interior design of the Dong settlements. For this, a range of pictures and historical facts (e.g., demand for fire ponds and balconies, ornament usage, etc.) was analysed. The study suggests fir timber as a basic ecological resource for wooden house buildings. Yet, it is highly flammable and increases the fire risk. A brief discussion on the cultural heritage of the Dong people and its influence on their building system is presented. The present findings can be used in future eco-design projects as a brief guideline for creating a traditional-style ethnic wooden house.

Introduction

The ecological design (or eco-design) discourse has reached a global dimension over recent decades (Qi et al., 2021). Different countries have adopted unique ecological norms and concepts (Bahrami, Jakobsson, and Söderroos, 2023). While Europe benefits from a successfully adopted passive housing scheme, the Middle and Far East continue to seek unity with nature. The United States shows interest in the energy efficiency of housing (Bahrami, Jakobsson, and Söderroos, 2023). The goal of eco-design is to make the most sustainable housing from natural materials while causing minimum damage to the natural environment (Qi et al., 2021). In the context of the scientific and technical revolution, the concept of ecological design becomes gradually pragmatic and limited by technical requirements, design standards, and international regulations (Plouffe et al., 2011).

Nevertheless, eco-design remains a spiritual and practical phenomenon that embodies the cultural identity of a certain ethnic group (González-García et al., 2011). Ecological design is the embodiment of contemporary human desire to preserve their species and save the environment in its primaeval form. From this perspective, ecological design plays not only a functional but also a spiritual role in human-environment interaction, especially in conditions of increasing urbanization (Kalayci Onac et al., 2021).

A group of scientists, led by Chris Perry, a founder of Pneumastudio, has created a project demonstration named "Not for 'us' alone". It demonstrates possible and close consequences of human influence on different forms of life on Earth (Kallipoliti, 2018). The general description of the project denotes a big part of soil together with flora and fauna inhabitants, which were displaced from their natural habitat. It has been done to demonstrate human-non-human connections within the natural environment. Ecological resilience has become a key aspect on the ecological agenda.

In the existing literature, considerable attention is paid to the global, continental and country-level features of ecological design, while ethnic groups as independent microenvironments receive little attention (Grabner, Buchinger, and Jeitler, 2018). This gap in the ecological design research can significantly affect the overall development of contemporary architecture, for the world is not a unitary single system. It consists of separate conceptual parts – ethnic groups – each distinguished by specific architectural and cultural patterns that dictate the general architectural trends of a nation.

The novelty of this study lies in the examination of how traditional wooden houses ecological design and the natural resource optimization course in the construction industry affect the construction practices of the Dong ethnic group. This study presents a significant contribution to determining the general trend of ecological design development and the effect of ethnic architectural microconcepts on sustainability and resource optimization.

Literature Review

At present, wood continues to be the optimal resource for ecological construction: it is energy-efficient and biodegradable, has a vast number of application options, denotes the do-no-harm-to-the-environment principle, and has an aesthetic appearance. Wood-frame buildings are associated with substantially lower-life-cycle carbon emissions compared to concrete-frame buildings (De Araujo et al., 2016; Fletcher and Goggon, 2001). Subsequently, wood-based frames can effectively address finite resource depletion and the accumulation of non-biodegradable waste in terrestrial and marine environments (Coloma-Jiménez, Akizu-Gardoki, and Lizundia, 2022).

According to the 2018-2021 statistics, the percentage of private timber dwellings varies significantly across the globe, ranging from 26-30% in the United States to 35% in Asia (De Araujo et al., 2020) and 40% in Europe (Ottelin et al., 2021). Due to the widespread use of green design and resource optimiza-

tion strategies, it has become a successful tool of influence in the hands of international construction companies. To date, this concept affects fluctuations in the global economic market, subjecting it to its requirements and parameters of development (Jang et al., 2015). Under the influence of environmental trends, some green design standards have appeared, becoming a key characteristic of certain regions or countries. Some examples include the US Leadership in Energy and Environmental Design (LEED), the UK Building Research Establishment Environmental Assessment Method (BREEAM), Singapore's BCA Green Mark, and Australia's NABERS rating system (Wood et al., 2016).

When considering green construction, architects usually draw attention to a variety of focal points, such as raw materials, labour, machinery, construction certification and more, following the motto: "Let us save the Earth for our children!" These points often become the cause of political manipulations (Bahrami, Jakobsson, and Söderroos, 2023). For instance, China with its population of 1.5 billion people treats the issue of environmental protection and resource conservation as particularly acute. This apparent rise of interest causes the unveiling of a strict green construction policy, which integrates the international strategic planning platform GGP (Geng and Doberstein, 2008).

At the same time, some scientists highlight the primary importance of ideological and cultural components of the architectural design process (Ames and Shepard, 2019). The vast majority of historical Chinese buildings are made of wood. Such structures are practical, ecological, and quick to manufacture but they also have a low threshold of thermal efficiency (Recht, Schalbart, and Peuportier, 2016). Modern scientists believe that this problem can be fixed in modern wooden architecture using the latest energy-saving technologies. Some technologies involve the use of timber-framed modular systems as the main building material. In harsh weather conditions (strong wind, frost), modular timber houses consume less heating energy (Gündoğdu and Birer, 2021). They also have a well-designed ventilation system, which provides high heat storage capacity (Schauerte, 2010). As can be seen, architects manage to make building projects energy-efficient, relatively cheap and culturally inspired (Ge et al., 2022).

In the scientific community, considerable attention is paid to the theory of natural environment importance and its influence on people's well-being and behaviour. It has been proven that daily contact with nature, in particular with natural materials, significantly improves one's well-being, emotional state, and spiritual fulfilment (Liu et al., 2022).

Mankind, due to increased technological progress and total mechanisation, has disturbed the balance of the environment. Environmental pollution itself has become one of the key issues on the global ecological agenda for future generations. The concept of eco-architecture has developed as a result of this understanding. The main criteria of ecological design include:

– positioning of buildings using a rational ecological approach;
– solving issues related to the design of buildings, their shape, organization in space, choice of materials, installation of a sanitary system, etc.;
– minimizing the use of non-renewable energy and limiting the resources needed during building operation;
– rational usage of natural ecological systems (giving preference to solar energy, natural air conditioning and green spaces);
– minimization of soil pollution and water basins contamination;
– construction site with minimal damage to the natural environment.

Ecological design denotes sustainable systems that function according to agreed ecological criteria, integrating human society and the natural environment for the benefit of both. In terms of ecological criteria, S. Kellert's approach should be mentioned. It contains six important elements, three of which were environmental specifics, natural shapes and forms, natural processes. In other words, the first three elements are directly connected with nature. The next element is light and space; it needs not only nature conditions but also space. The last two elements are fully place dependent and need people (people-nature relationships, people-space relationships; Li, Chau, and Aye, 2020).

At the same time, insufficient attention is paid to the issue of the influence of the features of private housing construction on the life of minority society, in particular, the ethnic group in which the so-called green construction takes place. There is also a lack of significant scientific research on optimizing the use of natural resources in ethnic environments and the impact of such optimization on the country's economy as a whole.

Problem Statement

This study is concerned with optimizing the ecological design of wooden structures and gathering new data about the key characteristics thereof. The focus is on China's ethnic sub-culture as an example. The aim is to analyse the ecological design of wooden houses in Dong villages (Guangxi province China) in accordance with ancient cultural philosophy.

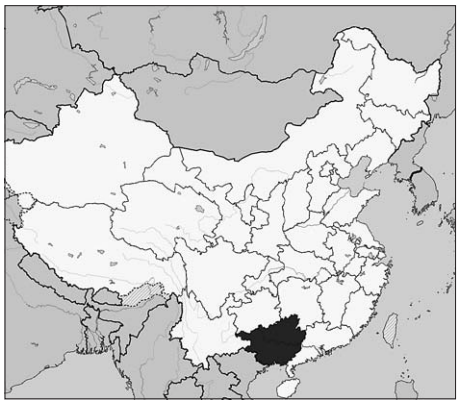


Fig. 2 Location of Guangxi within China

The objectives of the study are (1) to analyse the ecological and technical sides of the Dong-style eco-house design process and (2) to summarize the theoretical knowledge about resource utilization and optimization among the Dong people.

Materials and Methods

Research Design and Analysis

This exploratory multiple case study took place in the southwest of China in Guangxi province (Fig. 1). This research is connected with the question of ecological design of traditional Dong buildings, including also the basics of their settlement conception (topography, space orientation and plants) and design conception (building shape, spatial organisation, architecture). Buildings that were not recovered or decorated were taken for this purpose in the downtown area of Dong village. 40 buildings were taken for the analysis (the majority of them were residential and only some were public). The analysis included a continuous 4-years experiment with building monitoring and photography documentation of received data.

According to 2020 statistics, this province has 50.1 million people (Ge et al., 2022). Dong architecture was chosen for the study as a main research subject. The study examines eco-design policies classified into 3 categories according to architecture-based interactions they cover: architecture-nature, architecture-human, and architecture-resources.

The *first category* embraces some construction considerations: location, type of construction, animalistic elements, and type of building (residential houses, drum towers, covered bridges, etc.). The *second category* concerns cultural peculiarities and contains three main pillars: religious ceremonies to be conducted before building architectural structures; spiritual linkage between tree planting and childbirth; and building with or in harmony with nature. The *third category* deals with design considerations: type of material, optimization of wood use, floor capacity, lighting design, and thermal comfort.

The analysis of the research results was carried out according to the selected criteria of ecological design. Thus, the structure of the analysed buildings, their exploitation condition (good, satisfactory, unsatisfactory) were considered. In addition, the ownership factor was also viewed: which of the buildings are private and which public. The list of the main criteria of the eco analysis also included an item regarding the selection of materials for the construction (stone, wood, bamboo, etc.). Particular attention is paid to the criteria of spatial organisation, environmental friendliness from the point of view of renewable resources, solar and wind energy usage. Design and decorations are another ecological aspect of the investigation.

Some multiple case studies discussed the content and meaning behind the ecological design of Dong-style wooden houses. Some energy saving principles of wooden houses construction were described by Li and Yao (2020). The ways of protection of the traditional Guangxi settlements as a clue to sustainable design development were named by Lu and Ahmad (2023). The findings show that these eco-designs follow the following three principles: being environmentally conscious (ecological principle), designing with rich cultural content (cultural principle), and resource usage optimisation (Vestin, Säfsten, and Löfving, 2021).

In previous research, the main method used to describe the Dong people's lifestyle and the places where they live was the life cycle assessment (Rossi, Germani, and Zamagni, 2016). This study used the given method to gather general information from pictures and historical facts collected between 2018 and 2022. The investigation covers the history of the Dong people in China from the Ming dynasty to the present. The life cycle assessment was used to analyse interior decisions, such as floor plans, lighting design, and thermal regulation solutions.

Future research can be expanded to include traditional house constructions other than wooden-structured. For example, the houses built of clay, timber, earth, stone or bamboo can be investigated according to their sustainability and usability. The comparative study may focus on the Sasui altar as one of the most significant public buildings in Dong village. The religious side of Dong people's life is prominent and should be studied deeply. Future research can also investigate other branches of the offsite wooden construction industry within China, including the effect of ethnic motives in architecture on the urban design process.

Research Limitations

The current investigation is limited by the shortage of to-date information about ethnic groups in China. Most data is general and not related to architecture. Though the style and characteristics of ancient Chinese wooden buildings are recorded in many ancient books, it is difficult to find comprehensive information about pole-and-rail constructions in each province inhabited by ethnic minorities separately.

The majority of wood structure buildings classification gather theoretical information about all southern minorities in general.

Results

The ecological designs examined in this study reflect two aspects of Dong architecture: (1) the harmonious coexistence between architecture and its natural environment – settlement conception, and (2) a strong connection between architecture and humans in particular – design conception. The ecological character of wooden-stilt house designs in Dong architecture manifests itself in the construction site and appearance.

Settlement Conception

• Topography and space organization – As for the sun orientation, 32 buildings were placed (80%) with respect to the sun path, other 8 – were not appropriately oriented (20%). 25 dwellings (62.5%) were placed in accordance with dominant wind, other 15 buildings (37.5%) – were not. It can be stated, that the majority of buildings were built in accordance with energy usage minimisation criteria because these passive climate techniques help reduce the necessity of energy consumption.

Most houses were built in a place surrounded by mountains and bodies of water; the architectural structures were constructed in a shape of a fir tree. The private residential buildings are built along the slope. The Dong people mostly live in the mountainous areas of Hunan, Guizhou, and Guangxi, where flat and open land is a scarce resource. Adapting to the terrain, buildings stand on wooden pillars of varying heights, which allows levelling with the terrain without damaging the natural environment too much. The use of stilts also enables optimal resource utilization on the limited flat land. As rural tourism continues to develop, architects seek to construct residential buildings in a certain manner that will promote the coordinated development of the economy and environment.

• Planting – Analysed settlement is placed in a natural environment, where humans and nature interact with maximum sustainability. The settlement is located in the river bed. Traditionally, it is protected from different sides by forest and mountain range. This keeps the land from shifting during heavy rains and also minimizes the influence of wind. Traditionally, the view of environmental culture among local residents implies maximum non-interference in the natural environment.

Design Conception

• Structure of buildings – Structural state of chosen 40 dwellings under analysis was as follows: 15 in a quite good condition (with some traces of initial degradation; 37.5%), 19 in an adequate condition (with visible material and structural degradation; 47.5%). 6 buildings were in unsatisfactory state in (with strong material and structural degradation; 15%). This aspect demonstrates the sustainability of buildings if they are saved in good and optimal condition in the majority of cases.

• Ownership factor – As for the ownership criteria of chosen 40 buildings, 37 of them were private residential houses (93%) and 3 – public ones (7%), including Drum Tower, Wind and Rain bridge, and the village gate.

The wooden Dong buildings serve both residential and public purposes. Examples of non-residential buildings include, but are not limited to, the drum towers, wind and rain bridges, walled gates, and well pavilions. All these buildings are symbolic of the Dong culture. The Drum Tower (Fig. 3) was built entirely by local dwellers to defend against foreign enemies. The drum towers reflect Dong nationality and social cohesion in Dong villages.

The Wind and Rain Bridge is another architectural structure of public significance in the Dong community. The covered corridor of the Wind and Rain Bridge shelters people from the winds and rains (Fig. 4). It also houses shrines and altars to worship specific gods, thereby transmitting the religious beliefs of the Dong people.

As the only entrance to the Dong village, the walled gate is the nodal point in the village landscape, but it also resembles a ceremonial focus. In ancient times, it was used to prevent theft and defend people against foreign invasion (Fig. 5). Today, it retains its welcoming and inviting role (such as toasting and singing songs at the "Zhaimen" to show respect for the guests). In the past, the village gates were painted with mysterious cultural colour to prevent “demons” from entering the village. Dong village gates reflect the unique cultural beliefs of the Dong people, as well as their hospitality.

Fig. 3 The Drum Tower (Sanjiang, 2022)

Fig. 4 The shrine inside the Wind and Rain Bridge (Sanjiang, 2022)

Fig. 5 The village gate (Sanjiang, 2022)

Fig. 6 Fire pond (Sanjiang, 2022)

The timber dwellings reflect the cultural ecology of the Dong people. For instance, houses have fire ponds (Fig. 6), which occupants view as a gathering place for family activities. The balcony provides inhabitants of the house with enough space for manual work (e.g., embroidering, weaving), falling in love, and socialization (Fig. 8).

• Material selection – Among all analyzed buildings, 30 of them (75%) were made out of wood, and 10 (25%) – out of stone. In fact, used materials are natural and eco-friendly. By the way, stone buildings are quite ecological: they help cool indoors in summer while keeping them warm in cold season. Stone and wood composite buildings are both ecological due to the natural insulating properties of these materials. Therefore, the materials require less energy consumption during production and usage.

Dong architects use traditional locally sourced building materials, which come from local fir trees to reduce transportation. The main concern of sustainable construction is resource optimization, which refers to the use of land and building materials (in our case, timber). The most common material used in Dong houses is fir timber, and there are some rules among Dong people on how to utilize it properly. Fir wood comes in varying lengths and thicknesses depending on its building application. For example, central pillars located in the middle of the interior space are the tallest and thickest columns in the construction, while shorter pieces of wood can serve as gold and eave pillars. Finally, melon pillars are the shortest among all upright columns in the structure (Fig. 7).

Fig. 7 Wooden pillars of varying lengths in the Dong building (Sanjiang, 2022)

The earliest roofs in Dong houses were made of bark tiles, which is an example of optimal resource usage. The architectural wooden structures are mobile. If the building needs to be moved, one can mark the position of its individual parts with special symbols, then disassemble the entire structure, and put it back together in the new location. If the building is partly damaged, the layout material can be replaced.

• Building envelope – The indoor space utilization of Dong houses is high. The ground floor is for storing farm tools and keeping domestic animals. The second floor serves as a living quarter with windows providing the best lighting for routine activities such as embroidering, weaving, etc. The middle of the room is darker and serves as a bedroom space. The third floor is for grain storage. Modern Dong timber buildings are higher than the traditional ones. Some villagers have transformed their houses into homestays. The first floor is no longer used for raising livestock. The rooms above the second floor serve as guest rooms and master rooms.

Timber floors and partition walls can generate noise. To avoid it, double flooring is reinforced with a sound insulation cotton material or wall insulation slabs are used. Such a low-cost technology is a slight improvement upon the traditional ways of construction with the potential to promote the organic renewal of traditional architecture. Not to mention that it can meet the physiological and aesthetic requirements of contemporary people while maintaining the traditional style of Dong buildings.

Ecological thinking has influenced the Dong-style wooden building construction sequence drastically. Dong people have a range of ancient customs and ceremonies, one of which – tree planting – is to be conducted before the construction starts as a way to ask their relatives for support.

• Design and decorations – The wooden-structured public and residential buildings reflect cultural ecology through decor, which is crafted with love and reverence for nature. The Dong people express their worship of natural animals by incorporating embellishments into architectural design, resulting in distinctive emotions conveyed in unique ways. It can be a pig's nose, an image of a bird, or something else (Figs. 9 and 10). The Pig is associated with the period of harvest, while the Bird symbolizes hope for a better life.

One can also see different shapes (e.g., gourd fruit, flower, or bat) on the Dong-style roof ridges created with flat tiles (Fig. 11). Dong people use flower decorations in wooden eco-designs to express their yearning for a better life (Jin and Zhang, 2021).

To sum up, one should note that the results could be rather wider and deeper but some residential houses could not be examined because of the residents' reluctance. Some of Dong villagers didn't understand the importance of the analysis and prevented its development.

Fig. 8 Residential house balcony (Sanjiang, 2022)

Discussion

Ethnic wooden houses are a widespread phenomenon in China. They carry not only a special architectural flavour, but also embody the folklore features of the locals (Yuan et al., 2023). While the majority of the population is concentrated in cities, Dong settlements remain an ethnic focus of rural areas in Chinese provinces (Wang and Cao, 2022). The presented study examined the houses characteristic of the Dong settlement in southwestern China, in the provinces of Guizhou, western Hunan, and northern Guangxi (Yuan et al., 2022).

Dong residential and public buildings are built with the usage of fir wood. Among all analysed buildings, 30 of them (75%) were made out of wood, and 10 (25%) – out of stone. The building material used by Dong people in eco-design is environmentally friendly and recyclable (Pralea, Sficlea, and Pop, 2019). When burning, some elements such as propane-1,2-diol, acetaldehyde and C1–C8-carboxylic acids generate dangerous emissions that harm the environment (Schieweck, 2021). Fir wood can regulate seasonal and climate changes in temperature and humidity (Sipahi and Kulözü-Uzunboy, 2021). One of Turkish studies contains a case analysis of Mersin residential buildings (Gündoğdu and Birer, 2021). Considerable attention is paid to the sustainability question and to the aspect of settlement and design criteria contradiction. Therefore, it is mentioned that climate conditions strongly influence the state of buildings and residents' usage of renewable energy and ecological materials.

It also should be noted that Dong houses are not stable enough: 15 in quite good conditions (with some traces of initial degradation; 37.5%), 19 in adequate conditions (with visible material and structural degradation; 47.5%). 6 buildings were in an unsatisfactory state (with strong material and structural degradation; 15%).

Nevertheless, the building material is not without its drawbacks: it is mildly flammable and internal household items or accessories only increase the speed of fire spread. In ancient times, with the rapid spread of fire, Dong villages burned completely (Wang et al., 2022). That is why many modern architects hold the opinion about the need to combine materials for construction (it is optimal to use concrete structures but to landscape them with the help of individual parts; Kamalakkannan and Kulatunga, 2021; Mitterpach and Štefko, 2016; Wang et al., 2018). Housing open-oriented blocks also became very popular in 2016 among global building companies (Huang, Mori, and Nomura, 2023).

In modern ecological construction, there is a concept of a close relationship between man and the environment, which is interconnected like the threads of a web (Munro, Tavares, and Bragança, 2021). This relationship can be traced in both directions (a person should not only take from nature but also give to it in return, to maintain harmony and balance; Vilčeková et al., 2015). According to cultural and religious beliefs, Dong people must plant trees to give birth to their children. In their eyes, planting trees is equal to cultivating people. The children grow up, and the tree grows, turning into wood that can be used to build a house for the children to live in. In this way, the forest and trees can be lush, and the balance of climate and local ecology can be ensured (Monsjou, 2019). The same situation can be traced looking at the example of German eco-settlement Freiburg's Vauban. It demonstrates sustainable urban life with green city planning. The main specific of this region is a plenty of greenery and minimum of transport (it causes air and land contamination too). A net of pedestrians and paths for bicycles create a well-organised natural system (Küçük and Findik, 2020).

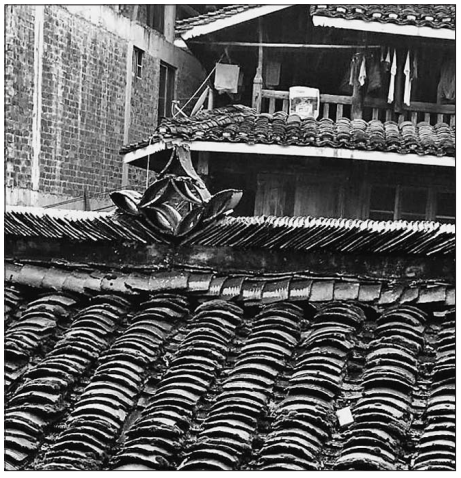
Ecological design deals tightly with the concept of social dimension (Kim et al., 2020). It can be easily traced to the example of Dong house-building traditions. Before building a house, one should first inform the mountain spirits and pray for success before starting to cut down the wood. There is a belief that natural objects have their souls and a certain type of thinking (Hill, 2017). Before building a house, one needs to choose a good time after the sacrificial ceremony. During the construction, relatives, friends, and people in the village come to congratulate and help. They will help each other in building the house. Such customs have been passed down from generation to generation, reflecting their simple and united national ideology (Hill, 2017).

As a scarce resource, land plays an irreplaceable role in the economic development of the Dong ethnicity. As for the sun orientation, 32 buildings were placed (80%) with respect to the sun path, the other 8 – were not appropriately oriented (20%). 25 dwellings (62.5%) were placed in accordance with dominant wind, the other 15 buildings (37.5%) – were not. Mountainous climate and territorial conditions strongly influence the way of building and interior design in particular (Hermawan, Prianto, and Setyowati, 2020). The rational use of land resources affects the population it can carry, the quality of the ecological environment, and the local economic growth rate (Dostatni et al., 2022). Summarizing the above-mentioned concepts and theories, it is possible to identify the basic principle of eth-

Fig. 9 The upturned eaves are decorated with bird figures (Sanjiang, 2022)

Fig. 10 A door frame featuring a pig's nose (Sanjiang, 2022)

Fig. 11 Flat tiles placed on the roof ridge to create a flower (Sanjiang, 2022)



ic eco-design peculiarities: a strong cultural and religious background that influences the way of building even in modern times.

Conclusion

This study highlights the following main factors influencing the ecological design of the traditional wooden architecture of the Dong ethnic group:

(1) Not enough space for construction and living in a mountainous area resulted in the two-storey (sometimes three-storey) building design. Moreover, 32 buildings were placed (80%) with respect to the sun path, other 8 – were not appropriately oriented (20%). 25 dwellings (62.5%) were placed in accordance with dominant wind, other 15 buildings (37.5%) – were not.

(2) Living in a rural area has influenced the Dong people's lifestyle; that is reflected in the outside architecture through the images of birds, domestic animals, and plants symbolizing a good harvest and faith in a prosperous future. 100% of analysed buildings had such inner and outer decorations.

(3) The cultural aspect affected the timber building design in several ways. The architectural structures are designed in a manner that allows worshipping spirits; the construction process itself takes place with the involvement of relatives and friends; and members of the Dong community plant trees to promote birth. For the Dong people, it was extremely important to maintain a balance between man and the surrounding environment. Among all analysed buildings, 30 of them (75%) were made out of wood, and 10 (25%) – out of stone.

The practical value of the research lies in the scientific exploration of the ecological design of China's ethnic minorities, which has the potential to affect further development of ecological architecture in the country. The findings can be used in ecological design projects for the preservation of cultural heritage and identity. Future research can analyse other ethnic building concepts that involve other building materials. For example, the houses built of clay, timber, earth, stone or bamboo can be investigated according to their sustainability and usability. The comparative study may focus on the Sasui altar as one of the most significant public buildings in Dong villages.

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