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Construction Technologies for the Conservation and Adaptive Rehabilitation of Historic Buildings in Hainan

Xinyang He

Hainan Vocational University of Science and Technology, Haikou, Hainan, China

Abstract. The historic buildings of Hainan fall into several distinct families — the arcaded Nanyang-style shophouses known as qilou, Qiong-style ancestral halls and academies, traditional Li dwellings, and ancient Confucian academies — and together they form the material record of an island culture shaped by local, maritime and minority influences. Under a climate marked by heat, high humidity, frequent typhoons and strong salt-spray corrosion, these structures commonly suffer decayed timber, weathered masonry, leaking roofs and inadequate structural stability, while conventional repair practice no longer meets the demands of modern conservation and reuse. Working from the region's climatic conditions and the actual state of the surviving stock, this paper sets out the governing principles for conserving and adaptively rehabilitating historic buildings in Hainan, reviews the key construction technologies in condition diagnosis, defect treatment, structural strengthening, façade restoration and functional renewal, and draws on local projects such as the Wenchang Confucian Academy and the Haikou Qilou Historic Street to analyse the difficulties encountered on site and the technical measures that matter. The aim is to reconcile authenticity of appearance, structural safety and contemporary usability, and in doing so to offer a construction reference for the long-term preservation, viable reuse and sustainable transmission of Hainan's historic architecture.

Keywords: Hainan; Historic Buildings; Architectural Conservation; Adaptive Rehabilitation; Construction Technology.

1. Introduction

Hainan possesses a distinctive island history, and many of its historic buildings carry both strong regional character and cultural value. They range from the qilou quarters of Haikou, which grew out of the Nanyang trade, and the Confucian academies of Wenchang and Yacheng, which embody orthodox ritual culture, to the boat-shaped houses of the Li people, the former homes of overseas Chinese in the modern era, and fort sites along the coast. Together these buildings constitute the principal physical heritage of the province's towns and countryside. As the construction of the Hainan Free Trade Port and the renewal of urban and rural areas gather pace, a large number of these structures are ageing, functionally obsolete and poorly protected against disasters. Repair in its original form no longer serves the needs of cultural tourism and everyday occupation, yet indiscriminate alteration risks destroying the historic character and erasing the cultural grain of the buildings.

Conservation and adaptive rehabilitation of historic buildings is essentially an attempt to reconcile cultural transmission with urban development. Its core is to "preserve the old and extend the new" — to keep the historical appearance, structural logic and cultural content intact while using sound construction practice to improve performance and update function. Current protection work in Hainan suffers from several weaknesses: interventions are often generic rather than tailored to the locality, appearance is prized over structure, and repair is preferred to maintenance. No standardized construction system adapted to the island's particular climate has yet emerged. With this in mind, the present study draws on the maritime climate of Hainan and the characteristics of its historic building stock to explore conservation and adaptive-rehabilitation technologies that are both scientifically grounded and practicable, in the hope of supporting the viable use of Hainan's cultural heritage.

2. Current State of Hainan's Historic Buildings and the Core Difficulties of Construction

2.1 Basic Characteristics of the Architectural Heritage

The historic buildings of Hainan are diverse in type and distinctive in style, and fall broadly into three families. The first is Qiong-style traditional architecture, represented by the Wenchang Confucian Academy, the Su clan ancestral hall and other academies and clan halls. These are mostly brick-and-timber structures with post-and-lintel (tailiang) frames, grey brick walls and dark clay-tile roofs, and they carry the ritual culture of the Central Plains. The second is the Nanyang-style qilou, concentrated in the emigrant hometowns of Haikou and Wenchang. Mostly built in the modern era as combined commercial and residential premises, they are timber-framed or of brick-timber and brick-concrete construction, blending Nanyang character with the building traditions of the Lingnan region. The third is the traditional dwelling of the Li people, typified by the boat-shaped houses of Chubao Village in Wuzhishan, with their bamboo-and-timber frames and thatched roofs — the most representative surviving example of Hainan's indigenous minority architecture. Because these buildings differ so markedly in construction craft, structural system and material properties, they place highly differentiated demands on conservation technology.



Figure 1. Nanyang-Style Qilou Buildings (Haikou Qilou Historic Street)



Figure 2. Traditional Boat-Shaped Houses of the Li People (Chubao Village, Wuzhishan)

2.2 Major Deterioration and Existing Problems

Under the combined assault of high temperature, high humidity, heavy salt spray and frequent typhoons, the deterioration of Hainan's historic buildings shows a distinctly regional pattern. First, timber defects are prominent: beams, columns and rafters exposed for long periods to humid air and saline aerosols readily suffer rot, insect attack, cracking and distortion, which seriously threatens structural safety. Second, the building envelope is damaged: grey-brick walls effloresce and crumble at the surface, render peels away, and thatched and clay-tile roofs leak badly, so that in a typhoon tiles can be blown off and roofs can collapse. Third, structural stability is inadequate: most old buildings were never designed for earthquakes or typhoons, and foundation settlement and loose members are widespread, leaving the structures unable to withstand extreme weather. Fourth, utilities have fallen behind: there is no proper water supply and drainage, electrical installation or fire protection, and ventilation and damp control are poor, so the buildings fail to meet the needs of modern use.

2.3 Core Difficulties of Construction

Construction for the protection and rehabilitation of historic buildings is considerably harder in Hainan than in inland regions. One obstacle is the climate itself. The year-round heat and rain, punctuated by typhoons, leaves only a short window for outdoor work, and in damp conditions repair materials cure poorly while the bond between new and old members is unreliable. Another is the strictness of conservation standards. Historic buildings must be "repaired as they were, in a reversible and verifiable manner"; large-scale demolition and reconstruction are forbidden, and the restoration of minor components and the faithful reinstatement of appearance demand great precision. A third difficulty lies in blending old and new techniques: traditional craft and the original appearance must be preserved while modern strengthening, damp-proofing and fire-protection measures are introduced, which calls for a careful balance between authenticity and safety. Finally, local materials are scarce. Traditional grey brick, timber and thatch are no longer produced in quantity, and substitutes must be reconciled with the original appearance while

performing adequately.

3. Basic Principles for the Conservation and Adaptive Rehabilitation of Historic Buildings in Hainan

In line with the requirements of the *Hainan Provincial Plan for the Protection and Transmission System of Historic and Cultural Heritage in Urban and Rural Areas (2024–2035)* and the *Technical Guidelines for the Protection and Renewal of Historic Buildings in Hainan*, construction work on historic buildings in the province should follow four core principles that govern procedures and technical standards.

The first is authenticity. The original layout, structural form, components, craftsmanship and historical grain of a building should be retained as far as possible so that the historical information it carries is not lost. Repair should give priority to traditional materials and traditional techniques, and any over-decoration or alteration that would alienate the building's character is to be avoided.

The second is reversibility. Every intervention — whether strengthening, renewal or the addition of new components — must be reversible: nothing added may damage the original fabric, and everything introduced should in principle be removable later without harming the structure or appearance, leaving room for future conservation.

The third is safety first. Given the typhoons, torrential rain and damp of Hainan, structural safety, disaster resistance and protection against moisture and corrosion come first. Through sound strengthening and the treatment of defects, the seismic, wind, waterproofing and anti-corrosion performance of buildings should be raised so that they can stand securely over the long term.

The fourth is adaptive activation. Provided the historic appearance is respected, building functions should be adjusted to modern needs: infrastructure should be completed, and the buildings fitted for cultural-tourism display, public service and habitation. The guiding formula is protection first, adaptive use, sustainable transmission.

4. Key Construction Technologies for the Conservation and Adaptive Rehabilitation of Historic Buildings in Hainan

4.1 Preliminary Survey and Condition Diagnosis

Accurate survey and diagnosis are the precondition of sound repair. Before work begins, a full and careful investigation should be carried out using non-destructive testing to examine the foundations, beams and columns, walls and roof structure, and to determine precisely the degree of timber decay, the extent of hollowing and efflorescence in walls, the depth of structural cracks and the data on foundation settlement. These findings should be read together with archival records and evidence of the original craft so that each building can be graded by its condition and assigned to the appropriate category of intervention — routine maintenance, repair and rehabilitation, or relocation for protection — and a differentiated construction plan drawn up. Blind or indiscriminate work is unacceptable. Given the saline atmosphere of Hainan, particular attention should be paid to corrosion of metal members and salt damage to masonry, so that the key areas requiring anti-corrosion and waterproofing treatment are clearly identified.

4.2 Treatment of Regional Deterioration

For the defects most common in Hainan, treatment techniques tailored to the island climate are required. Timber members suffering mild decay or insect attack can be preserved in place by low-pressure penetration of an environmentally friendly preservative. Where beams or columns are badly decayed or deformed, the damaged portions are locally patched or spliced with timber of matching species and the repair follows the traditional craft, after which the whole member receives a salt-resistant protective coating to improve its resistance to moisture and corrosion. For weathering of walls, grey-brick masonry that has effloresced or hollowed has the damaged render removed and the salts washed from the surface before re-rendering with a traditional lime-mortar mix; cracks are closed by pressure grouting to seal the fissures and block the penetration of moisture. Roofing calls for a combination of waterproofing and typhoon resistance. Clay-tile roofs on traditional buildings are re-laid using the established technique, with joints repointed, leaks made good and the fixings of individual tiles reinforced so that the roof can better withstand wind; the thatched roofs of the Li houses are

renewed with treated thatch, and the drainage slope of the roof is adjusted to prevent ponding and leakage.

4.3 Structural Strengthening

Where the appearance of the building must not be disturbed, concealed and reversible strengthening is the preferred route to improved structural stability. Timber members that have bent or deformed are wrapped in carbon-fibre fabric or given hidden steel supports, so that the original members need not be replaced and both safety and authenticity are preserved; loose joints are repaired by traditional mortise-and-tenon work reinforced with concealed fasteners to restore the integrity of the frame. For walls and foundations, minor settlement is dealt with by micro-grouting to raise the bearing capacity of the ground, while old brick walls are given concealed tie columns and ring beams to improve their resistance to wind and earthquake — all such members being hidden within walls or above ceilings so that the façade is untouched. Finally, in view of the frequency of typhoons, the fixing of roof, eaves and façade elements is improved overall and concealed wind-bracing devices are added, raising the capacity of the building to resist wind loads.



Figure 3. Strengthening of Decayed Timber Members on a Traditional Structure

4.4 Façade Restoration and the Transmission of Traditional Craft

Façade restoration lies at the heart of historic-building conservation, and the work follows the standard of "repairing as it was". Where the carved decoration, mouldings and window ornaments of qilou façades have been damaged, they are reproduced from surviving prototypes by hand carving, restoring the characteristic texture of the Nanyang style; the timber doors and windows, plaques and painted decoration of the old academies and ancestral halls are repaired by hand according to traditional methods, matching the original colours, patterns and finish. In the choice of materials, local traditional building materials are preferred — grey brick, timber and thatch all suit the conditions of Hainan — and where new materials are introduced they are artificially aged so that old and new components read as one. Throughout the process, the works are recorded on image and video, and the traditional craft itself is retained, so that the transmission of skills proceeds alongside the restoration of appearance.

4.5 Adaptive Functional Rehabilitation

Functional rehabilitation follows the idea of "invisible renewal for adaptive use": modern services are provided without damaging the historic appearance. To counter the humidity of Hainan, concealed damp-proof courses are laid at the base of walls, openings and ventilation shafts are improved, and natural ventilation and dehumidification are encouraged so that walls no longer sweat and timber no longer moulds. Utilities are renewed by concealed construction: water supply, drainage and electrical conduits are buried within walls, ceilings and floors, and fire-, moisture- and lightning-protection equipment is installed to satisfy current codes and practice. Where spatial function is concerned, the interior layout is adjusted without altering the main structure or the original plan, so that the buildings can serve cultural-tourism display, cultural and creative enterprise, and folk-custom experience — uses that raise their practical value while leaving them intact.

5. Engineering Practice and Strategies for Optimizing Construction

5.1 Typical Engineering Practice

The restoration of the Wenchang Confucian Academy is a representative case of the conservation and rehabilitation of ancient architecture in Hainan. Against decay of timber, leakage of the roof and weathering of the walls, the works applied reversible repair techniques — partial replacement of members, anti-corrosion strengthening, consolidation of the roof and repair of the walls — which removed the structural hazards completely while preserving the traditional form and historical appearance of the academy. The rehabilitation of the Haikou Qilou Historic Street, for its part, concentrated on the restoration of Nanyang façades and the

activation of commerce: the refurbishment of elevations, concealed structural strengthening, the invisible renewal of infrastructure and the improvement of the street environment together restored the character of the historic quarter and revived its commercial life, offering a practical model for the rehabilitation of historic streets in cities. The project on the boat-shaped houses of the Li people in Chubao Village, Wuzhishan, responded to the character of minority architecture by renewing the traditional thatch roofs and strengthening the bamboo-and-timber frames against decay and insects, reconciling the preservation of the original appearance with the use of the village for rural cultural tourism.



Figure 4. Qiong-Style Traditional Architecture (Wenchang Confucian Academy)

5.2 Strategies for Optimizing Construction in the Local Context

Drawing on the climate of Hainan and on experience gained in practice, four strategies for optimizing construction are proposed. The first concerns the timing and sequencing of works. Outdoor façade repair and roofing should be completed during the dry season, when the typhoon and heavy-rain periods are avoided, while indoor strengthening and the laying of services can proceed throughout the year; in this way both quality and efficiency are improved. The second is to strengthen the regional adaptation of materials. Improved traditional materials capable of withstanding salt spray and high humidity should be developed, with better anti-corrosion, waterproofing and anti-ageing performance, while the look and feel of the traditional material is retained. The third is graded construction. According to the protection grade of each building, the site should be divided into core protection areas and areas of compatible development: in the core areas only traditional craft and reversible methods are admissible, while in the surrounding areas modern improved techniques may be used to enhance performance. The fourth is a long-term maintenance regime. After completion of the works, regular inspection and maintenance of anti-corrosion protection, watertightness and structural condition should be arranged, matching the long-term attack of the island climate, so that the service life of the buildings is extended.

6. Conclusion

The historic buildings of Hainan are an important material carrier of the island's regional culture, its emigrant heritage and the culture of its minority peoples. Their conservation and adaptive rehabilitation is a significant step towards the transmission of Hainan's history and culture, the growth of its cultural-tourism industry and the improvement of its towns and countryside. The heat and humidity, the salt-laden air and the frequency of typhoons give the defects of local historic buildings and the difficulties of working on them a pronounced regional character, which conventional techniques for general use cannot answer. This paper has reviewed the existing problems and construction difficulties of the various historic building types in Hainan, set out the four governing principles of authenticity, reversibility, safety and activation, and summarized the key technologies for condition diagnosis, defect treatment, structural strengthening, façade restoration and functional renewal. On the basis of typical local projects, it has proposed strategies for optimizing construction to suit the environment of Hainan.

The conservation and adaptive rehabilitation of historic buildings is not a matter of simple repair and redecoration; it is the organic union of cultural transmission and functional renewal. In the years ahead, construction work in Hainan needs to strengthen regional technical innovation, complete a standardized construction system adapted to the island climate, and hold the balance between the transmission of traditional craft and the application of modern technology, and between the protection of appearance and viable use. Through construction techniques that are careful, scientific and attuned to the locality, the historic buildings of Hainan can be conserved for the long term and brought back into sustainable use, contributing to the transmission of the province's cultural heritage and to the cultural development of the Free

Trade Port.

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