CONSERVATION TECHNICAL HANDBOOK

A GUIDE FOR BEST PRACTICES

Volume 6 | Interior Elements

ICOMOS SINGAPORE

URBAN REDEVELOPMENT AUTHORITY

Conservation Technical Handbook

Volume 6 | Interior Elements

Published in November 2019 by

URBAN REDEVELOPMENT AUTHORITY

Project Team

ICOMOS SINGAPORE
Ho Weng Hin
Tan Kar Lin
Wong Chung Wan
Yeo Kang Shua
Ryanne Tang Hui Shan
Foo Chin Peng
Jaclyn Chua Xin Hua
Rachel Lim Wan Shuen
Lauren Natalie Kirk
Trikasemmart Panyaporn

URA
Chou Mei
Teh Lai Yip
Tan Huey Jiun
Kelvin Ang
Lee Yan Chang

Book Design
Achates360

Book Template
Meranda Tang Ying Zi

Cover photograph by the late Jeremy San Tzer Ning:
Metal balustrade with cast iron floral motif along staircase, against a backdrop of polychromatic terrazzo dado, at Wellington House, 25 Grange Road.

CONTENTS

Preface

Urban Redevelopment Authority, as the national land use planning and conservation authority, is pleased to present this series of conservation handbooks. Through judicious planning, Singapore has conserved more than 7,000 buildings and structures since 1989. They cover different building types, architectural styles, scales and genres. They are our precious legacy that must be protected for current and future generations of Singaporeans.

This series is a culmination of URA's collaboration with ICOMOS Singapore, our local chapter of the International Council on Monuments and Sites. This worldwide non-government organization is the official Advisory Body to UNESCO, advising the latter on heritage, conservation and preservation matters and issues. It taps on the technical expertise and experience of ICOMOS Singapore members to take the protection of our heritage gems to a higher level.

The eight volumes in the series are designed as step-by-step guides to carry out best practices in conservation. They will aid those undertaking works on heritage buildings. They contain a wealth of insights gleaned from projects in and around Singapore, taking into account climatic conditions, materials available in the market, new techniques brought by technological advances, and the types of skills offered by the industry.

I hope building owners, developers, professionals in the industry, builders and others who are interested in this field will find this series rewarding. I believe we can foster a strong partnership to protect our heritage. Together, we can make Singapore not just a distinctive liveable city, but also a home that holds meaning for us all.

Chou Mei (Ms)
Group Director (Conservation & Urban Design)
Urban Redevelopment Authority

About This Series

Since the 1970s, when historic monuments were first granted legal protection and the first shophouses were rehabilitated, architectural conservation has evolved and taken root in Singapore. Heritage buildings form a significant part of our urban landscape today, as brick-and-mortar repositories of memories straddling generations and as treasured focal points for diverse communities.

In the early days, the main challenge was overcoming the prevailing perception of these historic buildings as crumbling, unsanitary and inefficient structures worthy only of demolition (though in need of rehabilitation, they are embodiments of artisanship, history and urban character). Another uphill battle was the polarized view that conservation is a zero-sum game in terms of economic growth and urban development (it is an indispensable component in all creative, dynamic, well-loved, liveable and competitive cities).

With growing appreciation and awareness of heritage, many have since come around to the idea that conservation is not about fighting change but about how it is managed. Across the city, historic neighbourhoods have found a new lease of life as places to live, work and play, and a growing number of national monuments have been carefully restored in recent years.

While much progress has been made and lessons learned in the past four decades, there is still much room for improvement in skills and knowledge of best conservation practices. This guide is intended to help bridge this gap by laying out the ways to identify and appreciate heritage attributes, understand historic materials and assess their condition, as well as the methods and principles of restoration and long-term maintenance.

Built heritage can be seen as a public good, and every stakeholder – including the owner, developer, authority, building professional, builder and user – serves as a custodian of these precious assets. There is shared responsibility to safeguard each historic structure and ensure its safe passage onwards to the next generation. This series is conceived to provide guidance along the way.

Dr Kevin Y.L. Tan
Founding President (2014-2019)
ICOMOS Singapore

About This Volume

Look out for box stories and margin notes such as this one, for more information, advice, or links to other relevant chapters of the series.

What do the icons mean?

General tips and advice

Concepts learnt in other chapters or volumes in the series

External references

Further reading and topical notes

Volume 6: Interior Elements is the sixth book in the **Conservation Technical Handbook Series**. It covers the main types of historic interior built-in elements found in Singapore, including in situ finishes (e.g. plasterworks), custom-fabricated items (e.g. carpentry), and industrial products (e.g. cast iron, tiles). Key challenges and principles in the conservation and maintenance of these elements, including common local indoor environmental issues and malpractices, are also addressed.

While advanced technical investigations and works would require specialist consultants and contractors, the Handbooks give decision makers and other stakeholders a basic understanding and overall idea of what constitutes good conservation/maintenance practice, to inform better management and works planning of the historic property.

Chapter 1 Introduction establishes the heritage significance and value of interior elements and covers the basic terminology, including an overview of staircase components and types. It addresses common issues encountered in the maintenance and conservation of historic interior elements, and lays out broad approaches and guiding principles for best conservation practices.

Chapter 2 covers elements constructed of **timber** such as flooring and built-in furniture, prevalent in historic interiors given the availability of the material and skilled craftsmen in the region. **Chapter 3** focuses on **metal** elements, from imported products such as ornamental stamped ceilings to functional fittings. **Chapter 4** looks at a range of common interior hard surface finishes from **in situ and precast** plasterwork and terrazzo, to various types of **tiles** including terracotta and mosaic. For easy referencing, the contents of each chapter are organised under these key headings:

Overview: The chapter begins with a general introduction of the historic types and variants of elements covered in the chapter, their local supply and production, and how or why the material came to be used in particular ways in Singapore's past building practices.

Common Deterioration and Diagnostics: This section presents the common defects and issues to look out for and their likely causes, as well as main methods for inspecting and diagnosing issues for the specific historic elements. Both simple visual and tactile methods of diagnosis as well as specialist investigations are outlined.

Conservation, Intervention and Maintenance: The last section outlines, for the specific elements or material, appropriate ways of addressing deterioration, from cleaning to repair, reinstatement and design enhancement, as well as long-term care and upkeep.

1 INTRODUCTION

Back to previous view

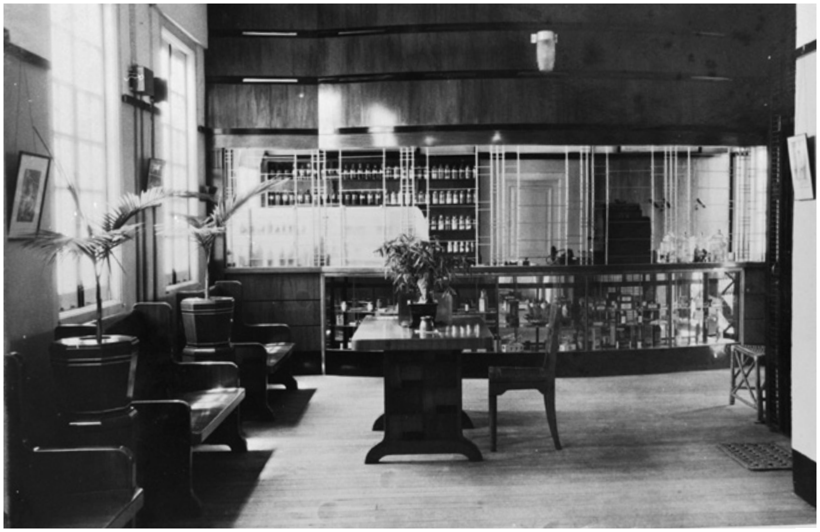
Overview

Elements found in internal courtyards, such as ornamental plasterwork and wall tiles in townhouse airwells, are mostly of similar construction to those on façades, and also subjected to the same exposed conditions. These are considered exterior elements; refer to the corresponding sections in *Volume 3 Facades* for more information on their maintenance, diagnosis of common issues, and conservation.

As part of the daily setting or actively used items of past building inhabitants, sensitively retained and restored historic interiors provide an immersive experience and convey the spirit of a past era with vivid immediacy and tactile detail. Such historic settings may be a living room, opium den, theatre hall, bank lobby, factory floor, classroom, and so on. Once part of a lived-in space, these interior elements and finishes embody an era's material culture and building practices and, where they are handcrafted, testify to the workmanship and artistry of the craftsmen. For civic, commercial and residential structures, key interior features are often the most high-quality or exquisitely crafted parts of a building.

This volume mainly addresses built-in or fixed interior elements rather than mobile ones such as loose furniture. These range from floor and wall finishes, built-in furniture, screens, vents, interior doors and windows, staircases and ceilings to light, sanitary and electrical fittings. They could be catalogue products such as tiles and fittings, made-to-measure like carpentry, or in situ finishes including ornamental plasterwork and terrazzo.

***Previous page**: The clean lines of 1930s modern interior design at the Japanese draper's shop, Echigoya, Middle Road.*



***Left**: Dispensary interior designed by Ho Kwong Yew (1930s).*
***Right**: Foyer, Singapore Conference Hall and Trade Union House (1965), by Lim Chong Keat.*

Back to previous view

Main hall, Singapore Civil Aerodrome (aka Kallang Airport, 1937).

Some fixtures are closely tied to specific building functions or operations, such as embedded tracks or hoists of an industrial workshop, or the projection room shuttering mechanism of a cinema – historic artefacts that instantly bring to life the rich stories of the heritage building.

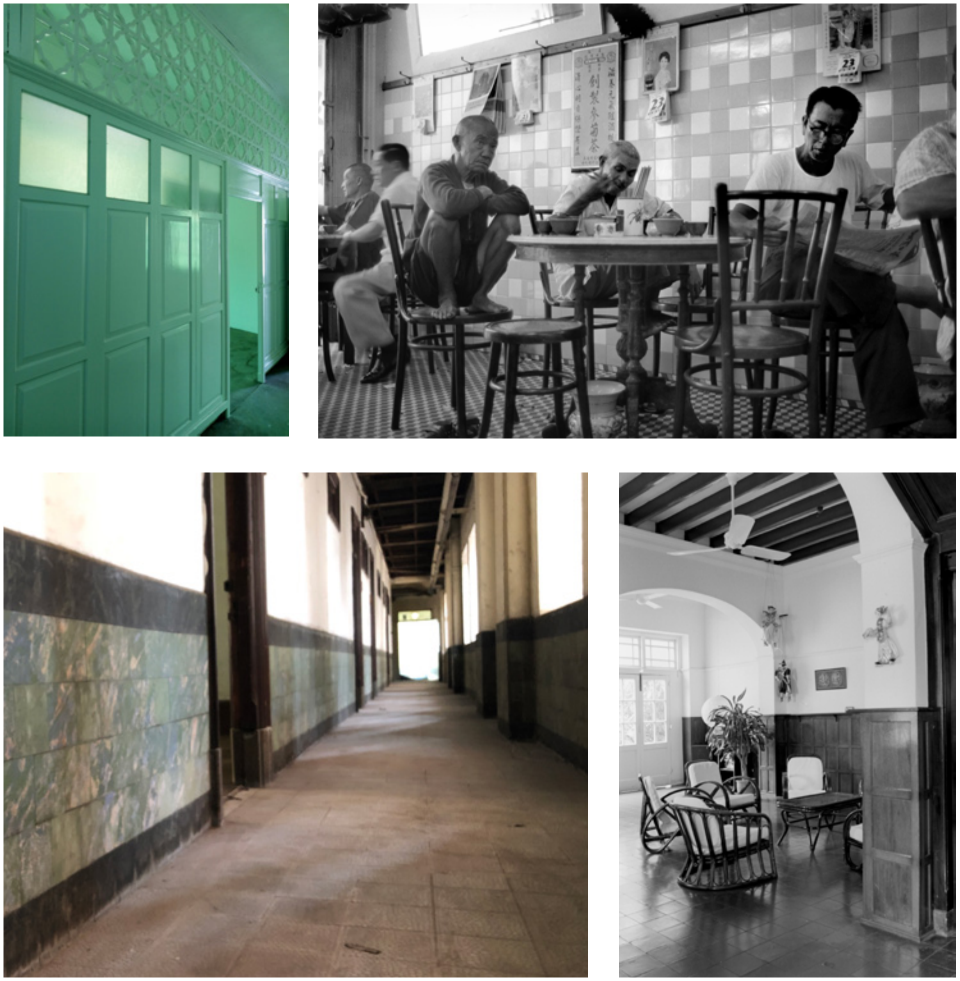
Unfortunately, heritage interiors are seldom recognized for their value and thus vulnerable to changes in building use, occupants' tastes, and building codes, often insensitively modified or even obliterated during renovations. These interior elements and finishes are a critical part of the building's heritage value and presentation, and in the rare cases where they are found intact, they should be carefully documented and conserved. Following is a brief introduction to some of the common interior elements found in local historic buildings.

Finishes refer to the materials applied or installed as the final layer on surfaces such as walls, floors and ceilings. Prefabricated finishing materials include timber (planks, parquet, panels), ceramic tiles and stone, while common in situ finishes are screed, plaster (plain, textured or moulded) and terrazzo. The substrate for these finishes may be structural or non-structural such as masonry walls, concrete floor and timber beams.

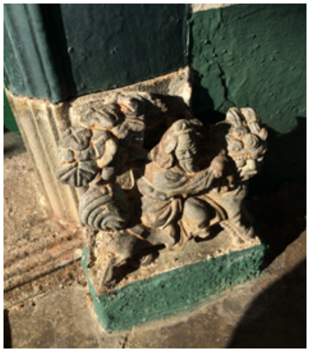
Back to previous view

Screens and partitions are non-structural half- or full-height room dividing panels that may be perforated to facilitate ventilation.

Dadoes refer to protective finishes installed along the lower half of interior walls that could be in tiles, timber panelling, textured or moulded plaster, paint or coating. Dadoes could be simple affairs when applied in service areas such as kitchens or bathrooms, or highly decorative when found in main spaces or public areas like living rooms and five-foot ways.



Clockwise from right: Carved timber screen and partition,Teck Lim Road shophouse; 1960s coloured glazed ceramic tile dado arranged in a grid pattern - a common feature of early coffee shops; timber panel dado, 1920s colonial government bungalow; rare surviving rubber tile dado, Tanjong Pagar Railway Station (1932).




Right: Ornamented carved granite heelstone with Chinese figurine, complemented by granite threshold, seen at a historic bungalow. ***Far right:*** Black terrazzo heelstones at the base of a timber door frame protect it from floor moisture. The heelstone is coordinated in design and crafted in situ with the red terrazzo threshold and skirting.

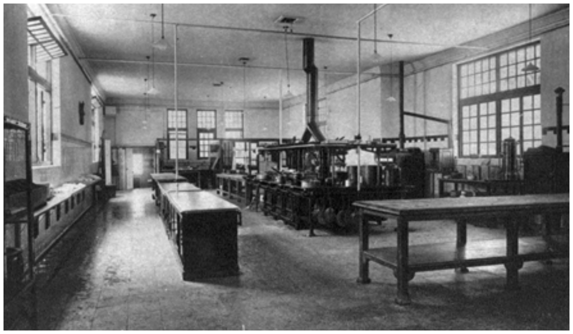
Skirtings are strips that overlap and protect the joint lines, providing a design transition between floor and wall finishes. Similarly, **cornices** can be found at the joint between walls and ceilings, while **architraves** mark the interface of door frame and wall. Doors may come with **thresholds** and **heelstones** made of more resilient materials such as stone, concrete or terrazzo in consideration of ground moisture. Together with dadoes, these elements visually relate to each other in the interior design scheme and usually feature simple mouldings. They are commonly in timber or plaster, while additional skirting materials include tiles, in situ terrazzo and occasionally stone.

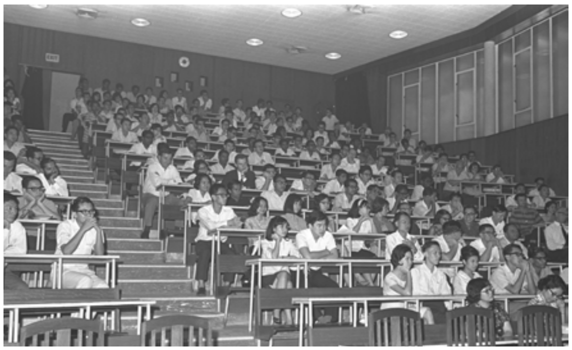
Built-in furniture and fixtures refer to items that are fixed rather than moveable, and sometimes customized to be integrated with the architecture elements of a building. Examples of fixed furniture include cabinetry, shelving, counters, seating and so on. Fixtures and equipment fulfilling specific functions include electrical and sanitary fittings, kitchen stoves and hoods, ovens and kilns, ticketing booths in a theatre or station, pipe organs in a church or concert hall, tracks, machinery, etc.


Right: Pre-cast concrete stepped stall display counter, Commonwealth Avenue Wet Market (1960). ***Far right***: Built-in concrete stove and hood connected to flue, 1950s flat.

Back to previous view

Top: *John Little & Co. Department Store (1890s)*
Above: *Church of the Blessed Sacrament (1965)*
Right from top: *Bank office, Battery Road (1890s–1910s); Kitchen, Sea View Hotel (1920s); First storey sales floor, Echigoya draper's store (1937); Auditorium, University of Singapore (Bukit Timah campus, 1950s extension).*





Back to previous view

This volume focuses on the conservation of exposed material or finishes of interior elements. For structure-related staircase issues, please refer to the respective chapters for timber, metal and reinforced concrete in *Volume 4 Structure* for more information on their diagnosis, conservation and intervention.

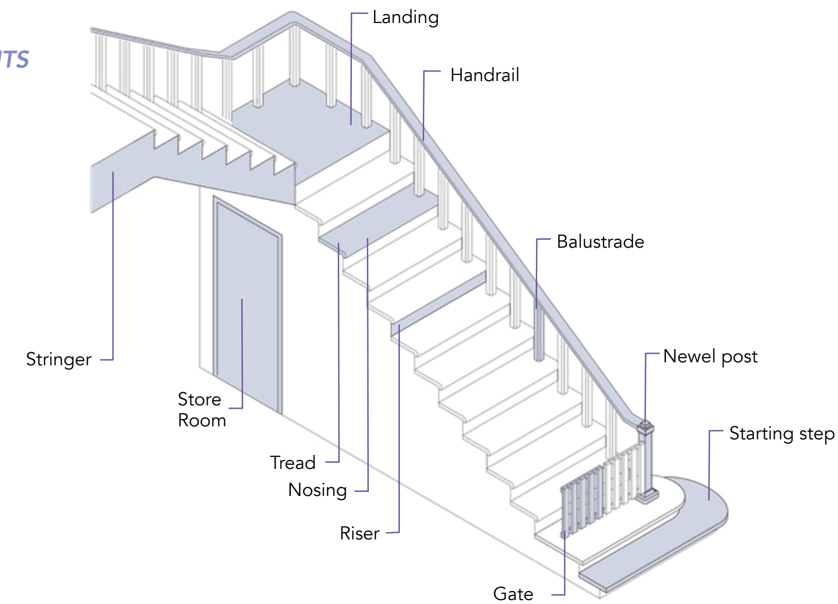
STAIRCASES: OVERVIEW AND TYPES

A staircase may perform the roles of structure, architectural element and interior feature all rolled into one. Often an extension of the structural frame, staircases provide **vertical circulation** in a building, connecting different levels, and are also an important character-defining heritage element in historic buildings. Depending on the specific location on plan and function, they could manifest as simple service stairs tucked at the back of houses, escape stairwells of high-rise buildings, or elaborate living room centrepieces and grand ceremonial affairs in public buildings. Staircases have evolved complex geometries and variations in design to suit different needs, as captured in the 1820 manual by Peter Nicholson, *A Treatise on the Construction of Staircases and Handrails.*

Main staircases are often grand and elaborately ornamented, replete with added features such as stone starting treads, gates, ornamented railings and balustrades. Sometimes small storage rooms are incorporated underneath. On the other hand, service staircases are often austere and functional, usually housed at the building's rear or its exterior. Different elements of the staircase can be customised to the smallest details, making their designs versatile. The variety of staircase designs and ornamentation across Singapore is testament to the skills of early carpenters and craftsmen.

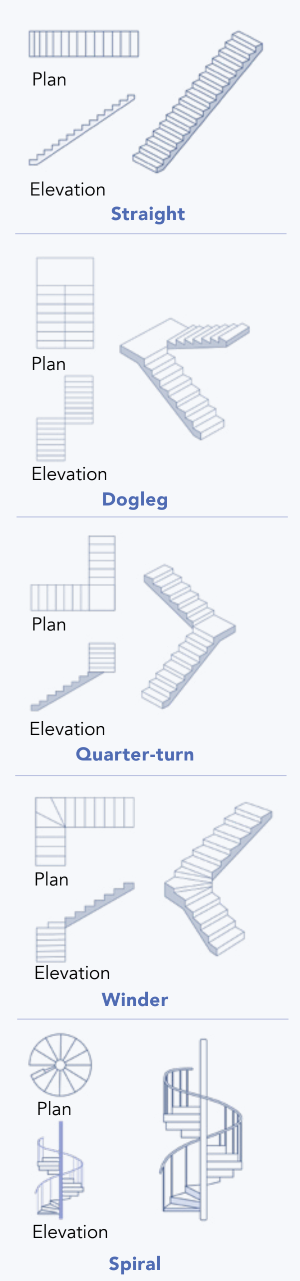
Historic timber staircase with winder steps and storeroom tucked into the undercroft.

STAIRCASE COMPONENTS



Back to previous view

BASIC STAIRCASE TYPES



A number of stair types evolved to cater to various space constraints and architectural requirements, including straight, dogleg, spiral and so on. Intended for daily usage and constant live loads, the main stair structures, including beams, stringers, newel posts and treads, are commonly constructed of materials with load-bearing strength such as timber, metal, masonry and reinforced concrete (RC). Historic spiral staircases, usually for escape or service access, are often prefabricated 'catalogue' products – imported cast iron ones in the late 19th century, or later on, in precast RC. While staircases of timber, metal and masonry structures are commonly just painted or exposed, the typical basic finish for RC ones is screed. For custom made staircases, accessories such as balusters, railings and treads may be designed using a different material – such as a RC staircase with mild steel balustrade and timber handrails – or there may be a finishing material such as tiles, timber strips or terrazzo.

Far left: *1920s three-quarter-turn timber staircase of a colonial government bungalow (1920s).*
Left: *1890s cast iron spiral stairs assembled from prefabricated modular units, National Museum.*

Open-well spiral stairway with curved reinforced concrete stringer supporting carpeted treads with brass balustrade, National Theatre (1963).

ELECTRICAL AND SANITARY FITTINGS

Electrical Fixtures

Before the advent of electricity in Singapore, buildings were constructed and orientated to maximize the use of natural light and ventilation. To supplement the natural light, much of the artificial light in buildings was provided by candle light or oil lamp, and later on, gaslights. Towards the end of the 19th century, electricity was gradually introduced to Singapore town along with more permanent electrical fixtures.

In 1899, the newly rebuilt Raffles Hotel was among the first commercial properties in Singapore to house electric-generated fittings. Powered by its own private generator, the hotel was internally adorned with a network of call bells, ceiling fans and lights allowing its notorious and decadent parties to go on long into the night. Hotels, department stores and offices equipped with elevators proudly touted these as luxury features. High-end commercial buildings in town were among the first to embrace electricity, while many residential properties, especially on the outskirts of Singapore town, would not enjoy electricity until as late as the 1960s–70s.

Below from left: ***Historic ceiling fan with moulded timber blades; 1950s installed Indola wall-mounted fans at the Capitol Theatre; 'Pop art' style installation with red glass pendant lights clustered around a feature reflector light, Hotel Royal (1971).***

Below from left: ***Electrical light fittings and wall-mounted and ceiling fans seen in this 1920s photo of the dining room of Grand Hotel de l'Europe; main passenger hall of the Tanjong Pagar Railway Station, 1932. Large bronze box lanterns and a clock were suspended from the vast barrel vault roof.***

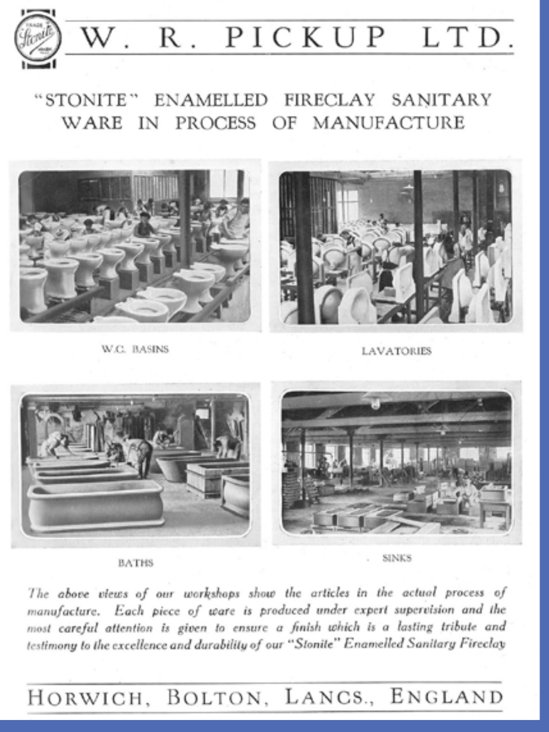
Sanitary Fittings

Throughout the 19th and early 20th centuries, bathrooms were usually erected as separate outhouses, keeping the odour away from the main house and allowing servants easy access to clear away waste materials. These would be collected at night by Chinese syndicates who would transfer the waste, or 'night soil', to plantations and market gardens at the outskirts of the city. The manual waste management system coupled with a hot and humid climate meant that diseases such as cholera and hookworm were rife in Singapore town.

From the latter part of the 1800s sanitary wares such as washbasins and cisterns were imported for use. These were typically made of impervious 'vitreous china' (enamel coating applied to ceramics) for the material's hygienic properties.

Piped sanitation and water supply was gradually introduced in the early 20th century, but mainly for the privileged.

'Modern sanitation', as it was termed, enabled the relocation of bathrooms into the main house, usually tucked at the back, fitted with taps, basins and tubs with built-in drainage, flushing toilets and so on. Meanwhile, the masses, especially those in rural areas, maintained the use of pit latrines, often shared by several families. It was not until the 1960s–70s that basic public amenities such as piped sanitation and electrical supply were implemented island-wide. This coincided with the opening of the first sanitary ware plant in Singapore in 1966. Using local ball clay and kaolin, Kaolin Ceramics Ltd produced items such as cisterns and washbasins for both the local and overseas markets.



1930s sanitary fittings found in the Tanjong Pagar Railway Station Hotel en suite rooms, with the imprint 'Stonite', a trademark of UK enamelled sanitary ware manufacturer W.R. Pickup Ltd.

Back to previous view

General Notes on Maintenance and Common Issues

Refer to *Volume 1 Introduction – Chapter 2, section on 'Developing a Maintenance Plan', and Chapter 3, section on 'Understanding the Main Causes of Deterioration'*, for an overview of conservation maintenance and common issues encountered.

Historic timber floor, especially in areas of heavy traffic, is prone to having its protective varnish worn off, as seen here, and should be scheduled for regular revarnishing.

Although generally well sheltered, many interior finishes and elements are subjected to **use (and abuse)** by building users on a daily basis, especially areas such as flooring and staircases. Yet others may be constantly exposed to certain **environmental conditions** that cause deterioration, such as kitchen fumes, bathroom moisture, harsh sunlight in west-facing room, and so on.

Regular, appropriate maintenance care, cleaning and upkeep are necessary to ensure day-to-day functionality and aesthetic appearance, and to prolong the lifespan of historic interior elements and materials.

- **Daily cleaning**: It is important to use only reagents that are chemically suitable with the respective materials for daily cleaning. For example, acidic chemicals should not be used for cleaning terrazzo tile flooring with cement binder base, as it will erode the tile surface by dissolving the calcite and carbonate.
- **Periodic checks** should be carried out on historic interiors to ensure that any problems are addressed early, rather than remaining undetected and left to aggravate beyond repair. The inspection should include defects in materials, joints and installation details.
- **Periodic treatment**: Protection, targeted repairs and enhancement are necessary from time to time, to lengthen the lifespan of the interior fittings and finishes. It is also good practice to carry out regular conservation treatment where appropriate.

Inadequate and inappropriate maintenance: Wet rot at the timber skirting may have been caused by constant exposure to moisture without sufficient ventilation or time to dry out. It was further painted over, likely to cover the initial stains, leading to trapped moisture and worsening of the untreated rot.

Conversely, many common issues arise from insensitive renovations, inadequate and/or inappropriate maintenance, resulting in premature deterioration, affected performance and loss of precious historic material.

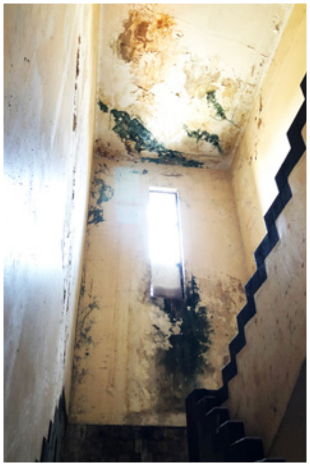
Air conditioning-related condensation issues can be minimized by buffering forseeable environmental changes. When the air con is switched off, the indoor temperature and humidity should be allowed to gradually rise, before opening the doors and windows. Vacated premises should also be regularly checked and maintenance carried out, when fenestrations should be opened to ventilate the interiors.

CHANGES IN BUILDING ENVIRONMENT

One major environmental change that Singapore's historic buildings are commonly subject to is the introduction of air conditioning. If not mitigated by careful mechanical engineering design, the resulting temperature and humidity difference between interior and exterior, as well as poor air circulation, may lead to recurring issues related to moisture and thermal movement. These include vapour drive drawing moisture through walls, condensation, mould/algae growth, loosening of joints and distortion.

Changes to interior spatial usage, such as the relocation or addition of 'wet areas' like bathrooms and kitchens, may lead to the deterioration of historic interior finishes or elements that are not designed for prolonged exposure to moisture or heat.

__Left__: Historic buildings left locked up and unoccupied for long periods become vulnerable to mould infestation in the warm and humid local climate. __Right__: Severe rusting of ornamented pressed metal ceiling due to moisture from condensation in the roof space arising from the introduction of air conditioning.



Left unaddressed, rain infiltration through a deteriorated building envelope eventually affects interior finishes and elements – in this case, extensive paint and plaster failure, and mould infestation.

NEGLIGENCE AND MAINTENANCE ACCESSIBILITY

Without appropriate and regular maintenance, wear and tear, ageing and breakdown of material are left unmitigated; problems go undetected and even worsen. With time this leads to an exponential increase in the cost of repair due to severe and extensive damage, or even irreversible loss.

Building envelopes function primarily as shelters for the interiors; any problems affecting roofs, exterior walls and fenestrations should also be addressed immediately – at the least a proper temporary measure should be put in place.

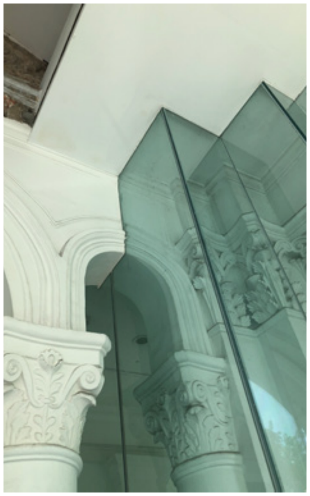
Some historic elements may be located at a height, such as clerestories or ceiling elements of high-volume spaces, and cannot be easily accessed for inspections or repairs. In many cases, they are hidden or obstructed by insensitive latter-day works, such as ornamental plaster above false ceilings, sealed windows, or wall dadoes blocked by partitions. Special equipment such as video probes and elevated access may be needed, incurring extra costs that may make owners reluctant to carry out regular maintenance checks. Elements that are hidden from sight are often forgotten in the long run and left to fall into disrepair.

Conservation maintenance inspection using temporary scaffold to access high-level mural wall tiles.

INAPPROPRIATE WORKS

Without a good understanding of the historic material properties and construction or the causes of damage/deterioration, unsuitable maintenance, repair and alteration works can lead to irreversible loss and damage.

- **Incompatible maintenance products and repair materials**: Off-the-shelf or easily available products in the market are commonly used for the maintenance and repairs of historic interior finishes and fittings, often for convenience. However, not all such products are suitable for use on historic materials in terms of physical, chemical and mechanical properties. Incompatible products and methods may in fact aggravate the problem, such as cleaning chemicals that react with components in the historic finish, causing surface erosion. A common mistake is the use of cement or very hard epoxy glue to patch or repair broken internal elements, which often ends up causing staining, moisture entrapment and cracking of the historic fabric.



Insensitive addition of glazed enclosure for air conditioning. Apart from the physical impact and compromised heritage presentation, there is insufficient space behind the glass for the proper maintenance of the ornamented plasterwork.

***Left**: Incompatible film-forming paintwork applied on ornamental plaster traps moisture, resulting in plaster deterioration. **Right**: Ornamental cement tiles stained by latter-day glued-on carpet.*

- **Poor installation or inappropriate methods**: Even with the right products, if the wrong installation or application methods are used, damage may occur. For example, applying restoration plaster and paint onto existing peeling paint and friable plaster – that should have been removed to the substrate level – will result in poor adhesion and delamination. For wood components originally secured by mortise and tenon joints, repairing by nail may cause the timber to split or crack.
- **Insensitive modification**: Historic interior elements and finishes, even if found to be in good condition, are often subject to insensitive renovation works, resulting in compromised heritage presentation and even irreversible loss. Originally exposed materials such as timber handrail, tile dado, stone steps or ironmongery are often painted over for an expedient 'makeover'. Cornices, architraves and dadoes may be damaged or hacked away when installing new cabinetry, while encaustic tiles are laid over with vinyl or replaced with homogeneous ones. Screens and vents originally designed to facilitate cross ventilation may be removed or boarded up when interiors are air-conditioned. False ceilings to accommodate service trunking and cables are a common addition that obscure high-level elements, including fanlights, vents, cornices, column capitals and moulded ceilings.

Back to previous view

General Notes on Conservation and Intervention

Refer to Volume 1 Introduction for an overview and more information on desktop and on-site studies, condition assessment, works planning, and main types of restoration works.

Brand and trademark imprints, such as this found on the underside of a 'Minton' encaustic floor tile unit, inform further research and provide clues on the material composition, manufacturing process, and dating of historic elements.

In the conservation and intervention of either specific elements or the entire historic interior, including the development of a long-term conservation management plan, the following study and preparatory steps should be followed through, prior to the execution of any actual works.

RESEARCH AND DOCUMENTATION

Study, archival research, and photo-documentation of the design, material, procurement and manufacturing history of the heritage element or finish, and mapping of its distribution through the building/s. This is to establish a base record of the historic item or finish as found, as well as its embodied historic/artistic value and building craft knowledge.

CONSTRUCTION STUDY AND TAGGING

Tactile and construction analysis should be carried out for the element or finish, such as timber joinery or floor build-up layers, and installation details. This will subsequently inform conservation and intervention methods, as well as the dismantling and installation sequence, should off-site restoration be necessary. For the latter, detailed location and reference tagging of each component is to be carried out during dismantling to ensure it is eventually reinstalled in the right place.

__Left__: Dismantling of historic teak staircase – the appropriate sequence and method are informed by detailed prior construction study. __Right__: Tagging of polychromatic cement floor tiles prior to their dismantling for slab reconstruction.

Back to previous view

CONDITION ASSESSMENT

Visual and tactile inspections should be first carried out to pick up any apparent **dilapidation issues**, and to establish their nature, cause, distribution and severity. Where recommended and budget allows, equipment-based non-destructive testing can provide more detailed assessment of problem areas, as well as uncover hidden issues. Where suspected, the presence of **hazardous materials** like lead paint and asbestos should be determined before carrying out any destructive works.

SOURCING FOR SPECIALIST BUILDERS AND COMPATIBLE MATERIALS

Interior heritage features are often well-crafted artisanal creations or early industrial products no longer widely available, such as carved timber screens or ornamental glazed ceramic tiles. It is highly recommended to engage specialist tradesmen with the necessary skills and knowledge in historic construction details, material composition and their physical properties, for the repair and restoration of these delicate elements.

Specialist builders may also be able to advise on the sourcing of compatible repair materials and replacement components that match the historic in terms of visual, strength, chemical and other material properties – for example, from specialist suppliers and salvage yards. Incompatible materials or methods may result instead in permanent damage – such as bimetallic corrosion from the use of a different metal type from the historic.

Skilled artisan putting the finishing touches on moulded plaster ornament.

Back to previous view

STAGING ACCESS

Some of the elements may be installed at locations that are challenging to access, such as high ceilings and cornices. Conservation and intervention works to these items by elevated access require careful staging, taking into account restricted opening size, limited headroom or available space, loading requirement, and elements vulnerable to accidental impact within the premises.

PROTECTION AND TEMPORARY ROOF

Adequate protection to these vulnerable elements should be put in place prior, such as padding, masking, bracing and so on. Where the existing roof may be dismantled in the course of an extensive conservation project, a temporary roof should be erected to protect vulnerable interior finishes from being exposed to the weather.

CONSERVATION AND INTERVENTION STRATEGIES

Based on the conservation tenet of **maximum retention** and **minimum impact**, repair methods and design approaches should be chosen not just based on cost effectiveness – those with the lowest degree of intervention and impact should be given first consideration. Beyond just retention, historic interiors should be given proper pride of place in the conserved building's overall scheme of **heritage presentation**, allowing for the full appreciation and enjoyment of these restored spaces and features.

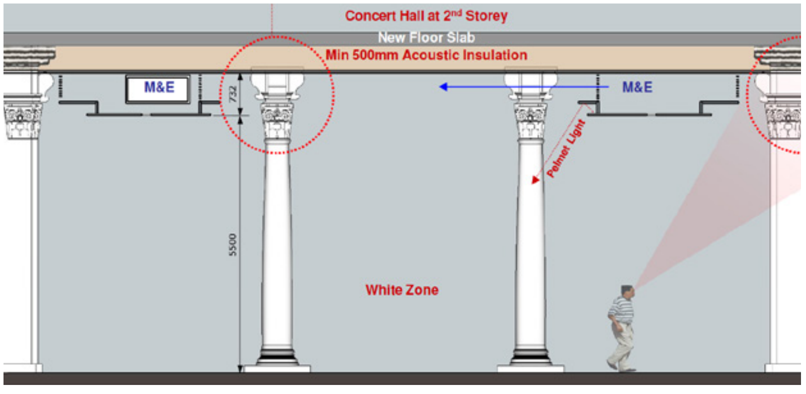
Right: *Protection of vulnerable interior elements from accidental impact during construction works.* ***Far right:*** *A secondary roof provides temporary shelter for the historic interiors while major roof works are under way.*

Back to previous view

Restoration of reed motif moulding with design enhancement of its deteriorated borders, and reinstatement of rectilinear field mouldings.

- **Conservation repair, reinstatement and design enhancement:** Historic elements assessed to be defective should undergo localised repairs and part replacement as far as possible, rather than replacement in entirety. Where available, matching salvaged historic materials should be used for repairs or reinstatement of missing items. Where there may be inherent design flaws or environmental issues to mitigate, design enhancement to protect and improve the material performance of the element should be considered.
- **Design integration and heritage presentation**: Historic elements that may no longer be operational or whose function has become obsolete, such as old ventilation systems integrated with cabinetry, or built-in stoves and kitchen hoods, should not be expediently demolished. These can be restored and retained as feature artefacts, or sensitively incorporated in the new interior design for a different use, e.g., as display shelving or a countertop.

Sensitive integration of mechanical and electrical services, such as air con and lighting, in the historic foyer space enables a full appreciation of the feature column capitals in Victoria Concert Hall.



Back to previous view

The 1950s Victoria Theatre seats were salvaged, dismantled into component parts, and upcycled into different interior design elements of the reconstructed theatre.

- **Historic spatial characteristics**: Beyond material finishes and elements, any adaptive reuse or planning consideration should take into account and retain/restore the heritage interior spatial characteristics, including scale (e.g., high ceiling halls, cellular classrooms), quality of light (e.g., light wells, clerestories, skylights), degree of enclosure (e.g., verandahs, rooms, open plan, division by screen/partition).
- **Managing alterations and services integration**: Where changes are needed, such as for code compliance, new uses or integration of M&E building services, these should be sensitively designed and strategically routed to avoid any adverse impact on high-priority heritage features. Installation methods and anchor points should not cause damage to existing heritage finishes and elements.
- **Managing additions**: In many cases the addition of ducting, trunking, equipment, or the need for display installation surfaces may call for boxing up, false ceilings and dry wall partitions that often end up obscuring heritage features such as column capitals, cornices, dadoes, etc. These should be limited to areas of lower priority and carefully detailed to minimize visual obstruction, such as false ceilings that recess away from the cornices and capitals. Additions also should not obstruct regular maintenance access of any historic elements.
- **Salvage and upcycling**: Where historic interior items cannot be retained in situ for various reasons, these should be salvaged where possible for repair of retained conservation components elsewhere in the building, and/or upcycled as a new design element. Reuse and upcycling of salvaged historic material is a good conservation practice that establishes historical continuity, promotes material authenticity, and is also environmentally sustainable.

2 TIMBER

Back to previous view

Overview

Chinese medical hall in a shophouse, with full-height built-in cabinetry and room divider screen.

Timber, given its inherent strength and the relative ease of working it into ornamented architectural elements, lends itself as a material of choice historically. In addition, there is ready supply of tropical wood from the region, as well as local and migrant skilled carpenters already steeped in their respective carpentry traditions.

The wide range of common historic timber interior elements includes flooring (board or parquet), partitions/screens, staircases, doors/ openings/vents, cornices/dadoes/skirting/architraves, built-in furniture, as well as **ceilings**.

Components, including carved ornamentation, are usually fabricated in specialist workshops before being brought to the site for assembly. Jointing methods may incorporate metal connections such as nails and plates, though these are not necessary for constructions applying sophisticated woodwork techniques such as dovetail joints and housings. Ornamented elements with moulded details such as newel posts and balusters are usually constructed from sawn timber – typically teak – that can be turned, planed and/or carved, and finished in wax or paint. Other timber species such as chengal and ironwood are also commonly found in historic building interiors. Particularly for elements subjected to high human traffic such as staircases and flooring, hardwoods are the preferred timber. Historic timber interior elements are commonly finished with **coating** or **paint** to provide a protective layer as well as for decorative or even didactic mural artwork.

Refer also to Volume 4 Structures, Chapter 3 'Timber', for more information on local timber supplies and common tropical hardwood used for carpentry works in the past.

Refer to Volume 2 Roofs, Chapter 6 'Ceilings and Soffits', for more information on timber ceilings.

Refer to Volume 7 Paints and Coatings for more information on this topic.

FLOORING

Timber board flooring is commonly found on the upper storeys or raised floors of local prewar buildings, as part of a timber floor system. Both a minor structural component and finishing layer, floorboards typically span across floor joists that are in turn supported off main beams or load-bearing masonry walls. Floorboards are joined mainly using the tongue-in-groove method where nails are hidden, driven through the tongue into the floorboard. Butt joints are also observed in older buildings where nails are driven directly from the top surface of the board to the joists below. Where the undercroft is exposed, the timber floorboards and joists also form the ceiling design for the storey below. Timber flooring is usually accompanied by **timber skirting**.

Parquetry, a floor finish comprising mosaic geometric patterns formed by small timber units, has also been used locally since at least the prewar period, manufactured locally or imported from around the region. It was seen then as a more sophisticated timber flooring with the warmth and attractive appearance of the material, without the issues associated with floorboards such as shrinkage and other distortion resulting in gaps or unevenness. Parquet units are usually laid and composed to showcase the grain of the timber, sometimes using different species with varying tones to create patterns. Teak from the region is commonly used for parquet flooring here. Usually highly polished, parquet floors require more frequent maintenance. In the postwar years, with advancement in woodwork machinery and to address the scarcity of resources, parquet units came to be prefabricated as composites using premium wood for the visible top layer glued onto cheaper hardwood below, integrated with tongue-in-groove interlocking details for easy installation onto the floor substrate.



Left: *Timber board flooring, Burkill Hall.* ***Centre:*** *Tongue-in-groove joints between floorboards revealed after dismantling of adjoining tiles.* ***Right:*** *Herringbone pattern parquet flooring.*

***Left**: Timber staircase with a bullnose starting tread and panelled undercroft. **Centre & right**: Ornate timber staircase with feature newel post.*

Carved timber newel post assuming the form of a dragon head.

STAIRCASE

Entirely timber staircases are commonly built as the main vertical circulation in prewar shophouses/townhouses and bungalows. Construction wise, these staircases are an extension of the timber floor system. These may be complemented by simpler back-of-house staircases for service/escape, of timber, precast concrete or metal construction. Domestic timber staircases are usually simple straight, quarter-turn, dogleg, or open-well flights, constructed essentially of solid timber treads on a structural frame of bearers, landing beams and newel posts. Ornamentation manifests on balusters, handrails, newel post caps, and even undercroft panelling as ornate carved timber and moulded profiles. Decorative paintwork may also be found on undercroft panelling and under-staircase storeroom partitions.

PARTITIONS, PANELLING, BUILT-IN FURNITURE

Joinery works such as partitions, panelling and built-in furniture tend to be made from relatively softer hardwood that has greater workability for decorative mouldings or carvings.

Back to previous view

Timber **partitions** range from simple, undecorated hardwood plank construction, panelled full-height walls or door-height room dividers, to screens. Highly carved removable feature screens in traditional Chinese houses are known as geshan (格扇 / 隔扇), typically carved using softer hardwood such as camphor, and finished with lacquer and/or gold gilding. Apart from ventilation, perforated screens also allow for some visibility while maintaining a degree of privacy and segregation.

Timber **dadoes**, half-height panelling that may be found in historic bungalows or public buildings, usually come with carved moulding. Unlike hard-wearing waterproof tile dadoes meant for kitchens and bathrooms, timber dadoes are mainly ornamental features installed along the walls of key spaces such as foyers, living rooms, libraries and so on. Dadoes are often coordinated in design with **skirtings, cornices, architraves and cabinetry**, providing visual interest and defining the spatial proportion of the interior space.

Historic timber **built-in furniture** commonly found here includes cabinetry, shelving, counters and seating. Typically constructed of solid wood, it ranges from elaborate Edwardian designs in the early colonial period to the clean geometric designs of Art Deco in the 1930s–50s.

Historic carved timber dado panelling.

Left: *Elaborate Chinese carved timber partition, or geshan, of a peranakan townhouse at 157 Neil Road.* ***Right***: *Full-height timber lattice screen with top vents and double swing door ensures security and some privacy while facilitating ventilation.*

From top: *Restored full-height moulded timber panelling, including cornices and architraves, 43 Amber Road (1900s); Grand timber coffered ceiling with moulded timber cornices, old Supreme Court (1939); Courtroom with timber strip wall cladding and built-in furniture, Subordinate Court (1975).*

Ticket booth with timber structure and carved panelling, Tanjong Pagar Railway Station (1932). A similar booth opposite housed a newsagent.

Stair hall lattice screen in tartan grid design, 1920s colonial government bungalow.

Art Deco newel post with geometric motif.

Back to previous view

Common Deterioration, Causes and Diagnostics

Refer to Chapter 1 'Introduction', General Notes on Common Issues and Maintenance for more information on the key principles and systemic problems related to deterioration and maintenance.

Given its visual and tactile appeal, timber is one of the most common materials used historically in building interiors. When kept dry and away from hazardous chemicals and fire, properly treated, well-crafted and well-maintained timber interior elements can last for hundreds of years.

VISUAL AND TACTILE SURVEY

Where there are historic timber interiors, it is generally a good practice to include these alongside the regular visual and tactile maintenance inspections of other similar elements, such as timber doors and windows. Common defects and potential causes of deterioration to look out for include the following:

- **Moisture ingress**: Long-term saturation of timber elements in moisture, for example due to leakage, ponding or condensation, will cause even properly treated tropical hardwood to become vulnerable to bacterial, fungal and insect attack. As such, any affected areas should be marked up during inspections and the cause of moisture ingress identified and addressed urgently.
- **Wet rot** is mainly a result of fungal attack that breaks down wood cellulose and lignin. Affected areas are often where water is easily trapped and retained within the wood, becoming conducive environments for infestation. These include the ends of wood embedded within or abutting masonry or reinforced concrete – for example, where floorboards, ceiling timber frames or partition frames are fixed onto the supporting wall or floor slab.


Long-term leakage and ponding on parquet flooring and timber strip ceiling causing extensive damage.

Back to previous view

Refer to *[Volume 5 Doors and Windows, Chapter 2 section on 'Common Deterioration, Causes and Diagnostics']*, for more information on termite infestation.

- **Insect attacks** in local historic buildings may show up as trails or 'tunnels', such as those created by **termites**, as well as frass – fine powdery refuse produced by boring insects.
- **General wear and tear, accidental damage**: Interior elements, being in close proximity to building users, may be subjected to daily use or frequent handling and are more vulnerable to accidental impact. This may result in worn-off coatings, loss of surface material or definition (e.g., for carved timber elements), dislodgement, scratches and punctures, especially for heavily used elements such as railings, staircases and floor finishes.
- **Inadequate or inappropriate maintenance works**: Overpainting could trap moisture, which may eventually lead to wet rot. Protective coatings such as varnish and lacquer that are worn off and left untreated, or failure to ensure the timber is kept dry and well ventilated, may also result in moisture-related issues. The use of inferior wood and poor or wrong fixing methods during repairs may lead to poor fit, premature wearing and deterioration, including cracks.
- **Inappropriate alteration works**: This includes ad hoc installation of fixtures such as cable trunking that punctures or is nailed onto historic timber, or insensitive modifications such as complete removal, instead of localized repair, of partially deteriorated elements, resulting in compromised heritage presentation and loss of heritage value.

Left: *Inappropriate paintwork led to trapped moisture, resulting in wet rot and termite damage.* ***Centre***: *Timber flooring protective varnish worn off by abrasion from heavy traffic.* ***Right***: *Constant wet mopping may lead to moisture ingress and wet rot along the floorboard edges and joints.*

Back to previous view

- **Gaps, splits and checks**: Overloading could cause floorboards, ceiling boards and partition panels to crack and split. Checks between old and new timbers, or gaps between planks may form when the replacement timber used for repairs is not adequately seasoned or of a different species from the historic.
- **Excessive building movement** such as settlement or thermal movement may result in dislodgement, cracks and deformation.
- **Environmental changes**: Most commonly, the introduction of **air conditioning** results in repeated fluctuations in temperature and relative humidity, causing shrinkage and expansion in timbers and resulting in splits and distortions in the long term. Internal condensation may also occur, leading to moisture-related problems such as mould and wet rot. Vacated buildings with fenestrations closed for long periods are also conducive to excessive mould and fungal growth on interior timbers.

***Left**: Minor splits at the ends of timber slats and insect infestation. **Right**: Timber shrinkage due to temperature and moisture fluctuation from air conditioning resulting in gaps between planks.*

NON-/SEMI-DESTRUCTIVE AND SAMPLING TECHNIQUES

The visual and tactile survey may identify more complex or potentially hidden issues that need further diagnostic methods to assess, ranging from non-destructive to semi-destructive tests and sampling extraction. Sampling and semi-destructive tests should be carried out at a less visible location on the target element.

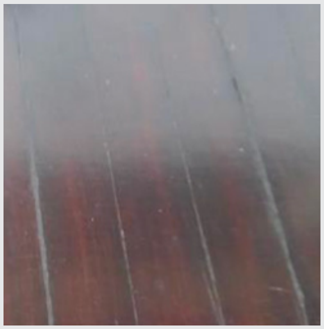
- **Moisture check** by the common 2-pin method is carried out to assess the degree of moisture retention in deteriorated components to determine the cause, condition and integrity of the timber member. Where the moisture content exceeds 20% of the dry weight, there is an increased risk of fungal attack.
- **Timber resistograph** is used to assess subsurface anomalies in timber members such as cavities, termite infestation, wet rot, etc. In this semi-destructive test, the equipment measures the force it takes to drive a needle across the timber section, to detect variations in density caused by decay and ascertain the extent. This allows the conservator to formulate intervention strategies for localized repair and consolidation instead of totally replacing the timber elements.
- **Prick test** is also a semi-destructive method to check the soundness of a timber surface. The tester inserts a sharp tool (e.g., a knife, screwdriver or ice pick) at an acute angle to the surface and lifts up a thin splinter. If a long and solid fragment can be picked up, the timber surface is likely sound.

Extracted sample of a historic timber element for microscopic study.

If the original finish of the interior element is some form of preservative or protective coating, and even painted artwork, **pigment composition analysis** and other investigations of the coatings and detailed documentation should be carried out prior to any interventions.

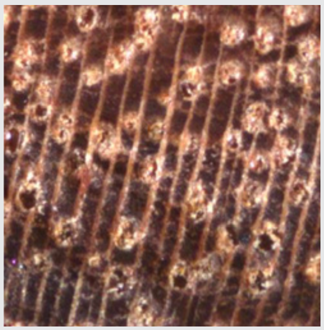
Refer to *Volume 7 Paints and Coatings* for more information on this topic.

- **Species identification** calls for sampling extraction by removing a small piece of wood for visual or microscopic examination. Timber of an identical species and treatment specification should be used for conservation repair, for better material compatibility and performance with the existing. Replacement timber must be of the same species or at least similar density and hardness as the historic ones to prevent differential deterioration, shrinkage, cracks and insect attack.
- **Others**: Other specialized investigative tests may be deployed depending on the dimension and type of elements – infrared thermography to check for moisture, wet rot and termite attack, Pilodyn test to check for wood density (for indication of fungus infestation, termites and presence of different wood species), or vibration, acoustic and microwave methods to detect active termite infestation.

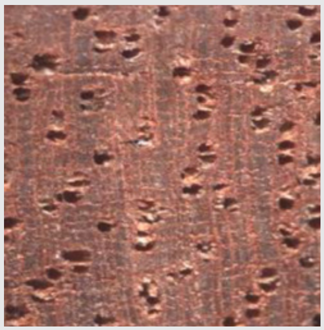


Timber floorboard (Verandah)

Timber floorboard (Room interior)



Chengal



Nyatoh

Microscopic images reveal different species used for verandah and room interior floorboards.

Back to previous view

Conservation, Intervention and Maintenance

Refer to Chapter 1 'Introduction', section on 'General Notes on Conservation and Intervention' for more information on the key principles and considerations related to conservation and intervention works.

Refer to Volume 4 Structure, Chapter 3 'Timber', section on 'Structural Repair and Rehabilitation', for deriving a criteria matrix for assessing condition and conservation works for historic timber.

Revarnishing of wood as a regular maintenance practice.

MAINTENANCE

Regular **visual inspection** should be carried out for all historic building interiors, even vacant premises, with particular attention to signs of insect activities and moisture issues. Air-conditioning-related condensation issues can be avoided by **buffering the environmental changes**, for example allowing the indoor temperature and humidity to gradually rise when the air-conditioning is switched off, before opening the doors and windows. For vacated premises, fenestrations should be opened regularly to ventilate the interiors for mould prevention. Minor repairs and conservation works may be called for as part of maintenance to address localized defects, or to undo past inappropriate works:

- Daily cleaning in general by regular dusting, vacuuming or dry wiping, and with gentle pH-neutral cleaner only if necessary, avoiding harsh detergents and too much liquid. Check and regularly remove any debris build-up in hard-to-reach areas.
- Maintaining a dry and well-ventilated indoor environment.
- Lubrication of hinges and ironmongery for cabinetry, dusting/oiling of timber components.
- Rectifying jammed or dislodged components.
- Redecoration of plain painted or varnished surfaces using appropriate timber paint or varnish (once every 5–10 years). Sand down worn, old layers and reapply compatible timber coating. Re-treatment with preservative may be needed after a certain period – specialist advice should be sought if in doubt.
- Disinfestation of pests, bacteria and fungi by contacting the relevant specialist.

Back to previous view

CONSERVATION AND INTERVENTION

A **skilled fine joinery carpentry workshop** experienced in working on historic timber should be engaged, under the supervision of a conservation specialist, to carry out timber conservation works. The condition of each element and component should be carefully assessed to determine the appropriate conservation approach, beginning from the lowest degree of intervention. Careful consideration should be given when deciding between **in situ** or **off-site restoration**. While bench restoration may offer better manoeuvrability, the process of dismantling may cause damage to the timber element and surrounding finishes. Timber elements retained in situ should be given adequate **protection** from accidental impact, staining or exposure to weather in the course of conservation works.

Depending on the extent of damage, below are the options to be considered for rectification and restoration work of interior timbers.

- **Paint stripping**: Inappropriate paint layers and stained varnishes that trap moisture, obscure historic details and obstruct operation should be removed via careful stripping by hand, using a combination of turpentine, wire wool and timber scraper. Past layers should first be recorded by paint analysis. Harsh chemicals and industrial sanding machines should be avoided as much as possible, as these will remove timber patination. Paint removal should not be carried out using hot-air guns or blowtorches due to high risk of fire hazard.
- **Surface patching**: For minor surface flaws and discontinuities such as pits, simple patching work can be carried out using a polyester-based or epoxy timber putty.

__Right__: Manual paint/ varnish removal from verandah balustrade by careful scraping. __Far right__: Following manual paint removal, surface patching is done on timber staircase elements by applying timber putty to minor cavities and uneven surfaces.

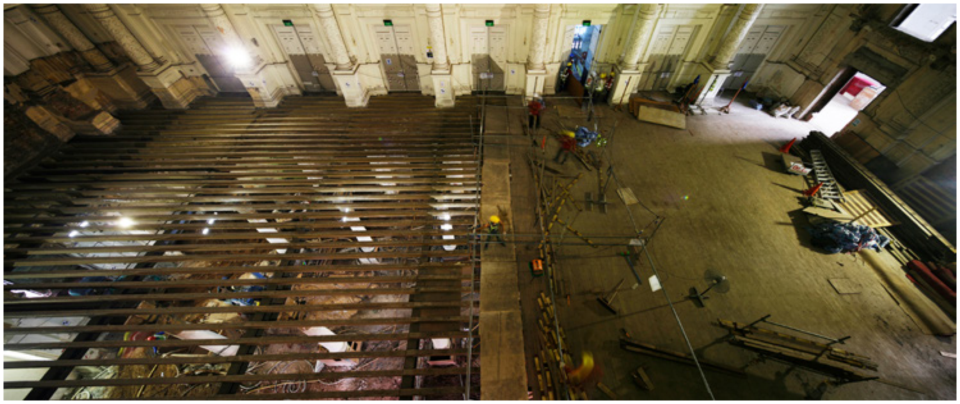
Back to previous view

Timber-to-timber repair by splicing.

- **Chemical impregnation** by injection with epoxy or polyurethane-based filler can be used to address cavities detected in medium-sized timber members such as screen and staircase components. This will consolidate weak points and restore integrity to the wood without sacrificing the historic material.
- **Timber-to-timber repair**, which is large-area surface patching or whole-section replacement by scarfing, may be required for more substantive defects. The species and properties (such as seasoning and preservative treatments, grain direction) of the replacement wood should match the existing, for performance compatibility. The scarf joint between new and old should take into account prevention of water ingress, high stress concentration, etc. These could be applicable for solid timber railings, panels, floor joists, screens, etc.
- **Reassembly**: Where large gaps are found between floorboards, a skilled joiner should be engaged to carefully re-lay all the boards to close the spacing, and any remaining gaps should be filled with added boards of matching timber, or salvaged historic planks. Timber filler strips may be used as a temporary measure until major works are next planned, or if disassembly of the timber floor may cause damage to other historic elements. Similarly, where components of other timber elements such as stair balustrades, treads and risers have come loose, they should be carefully disassembled, inspected for damage, repaired and reinstalled by a skilled joiner.

Dismantling of historic Burmese teak staircase - this will be followed by safe storage, bench restoration and reassembly after completion of the building's structural strengthening. The dismantling method and sequence should be informed by detailed construction study.

Back to previous view



***Left**: Filling in the gaps between floorboards with filler strips and timber putty following reassembly. **Right**: Dismantling of timber strip flooring, revealing the joists beneath.*

- **Localized replacement**: For repetitive timber interior units, such as ceilings and floor boards, balusters, etc., if some are assessed to be deteriorated beyond repair, localized one-to-one replacement may be necessary. For elaborate carved timber elements, the design and profile should be accurately documented for the record and to facilitate replication work, using methods such as 3D scanning, silicone moulding and photogrammetry. Wood species, dimensions, design and joinery should be identical to the original for the replacement timber, with adequate seasoning, treatment and moisture content, to prevent issues arising from incompatibility such as formation of checks.

Refer to Volume 7 Paints and Coatings for more information on this topic.

Upon completion of timber repairs, the surface of the restored windows and doors should be treated with **preservative** to prevent fungal and insect attack. Transparent or translucent **varnishes** can be used if the timber grain is supposed to be revealed, such as teak elements. Traditional natural material systems include linseed oil. Common resin-type coatings include clear or pigmented polyurethane, acrylic or alkyd polymer. If the surface is to be painted, polyurethane, acrylic or alkyd polymer-based **timber paints** are available for selection based on the application need.

3 METAL

Back to previous view

Overview

Refer to *Volume 4 Structure, Chapter 4 'Metal Structures', and Volume 5 Doors and Windows, Chapter 3 'Metal' and Chapter 6 'Ironmongery'*, respectively, for more information on the history of the supply and use of structural and non-structural metal elements in the local context.

Metal elements tend to be costly, especially for imported products **prefabricated** in overseas foundries and ordered from catalogues. They are selectively applied on historic interiors for their strength and material efficiency (staircases, deck flooring, brackets for handrails, light and electrical fittings), hygienic qualities (sanitary ware, professional kitchen fittings), high-usage durability (ironmongery), and potential for expressive design (balustrades, grilles, pressed metal panelling).

Common metals used for internal elements are broadly grouped into ferrous and non-ferrous metals. Elements with structural requirements such as staircases and railings are typically made of **iron** and **steel** – usually also the most prominent decorative metalwork in historic interiors. Other elements may be made of **brass**, **bronze**, **copper** and **lead** besides the more recent **aluminium** and other alloys.

Interior metal **spiral staircases** can be found in some historic churches and public buildings, usually as space-saving service access. A more ornamental design that doubles as an aesthetic feature may be chosen if it is located in a relatively prominent space, such as stairways to church choir lofts. Typically made of cast iron, spiral staircases come in step-sections, pivoted from a central post anchored to the floor and held in place by the baluster units. Metal accessories are also commonly used for timber, masonry or reinforced concrete staircases, such as brass or cast iron railings, and wrought iron balustrades.

Ornamental detail of cast iron spiral staircase ordered off a catalogue and assembled on site from imported prefabricated modules, Church of the Nativity of the Blessed Virgin Mary (1901).

*Metal ceiling "centre-flowers" as shown in a catalogue (**right**), and as found at a 1920s St Patrick's Road bungalow at (**far right**). "Centre-flowers" are part of the metal ceiling system that may serve as the anchor point for fittings such as chandeliers or fans.*

Brass and lighter metals are often used for ornamental lighting fixtures such as chandeliers, as well as ironmongery including door knockers and door stops.

Refer to Volume 2 Roofs, Chapter 6 'Ceilings and Soffits', for more information on metal ceilings and panelling.

Mild steel, iron and zinc are used to fabricate historic pressed/stamped **ceiling and wall panelling** with ornamental relief. The pattern of the panel is drawn and made into a mould and die. These are then used to form the metal panels either by stamping or pressing. A panel is typically less than 0.5mm thick, and nailed onto a timber frame structure supported off the wall or roof. These would become obsolete in the post-war period, when aluminium became affordable with improved extraction and manufacturing technology, and came to replace other metals in a range of products including wall and ceiling panels.

Refer to Volume 7 Paints and Coatings for more information on this topic.

Metal surfaces are often **coated and/or painted** to protect against oxidation, moisture and other environmental corrosive agents. For iron and steel, anti-rust primer is usually applied, followed by painting. Brass and bronze elements are polished with wax to prevent tarnishing by copper patination. Aluminium elements are normally supplied with their surfaces already pre-anodized.

Iron spiral staircase with brass railing, and iron deck floor, Raffles Lighthouse (1850s).

From left: *Bronze pendant lights, Supreme Court (1939), and Tanjong Pagar Railway Station (1932, light installed post-war).*

From left: *Cast iron spiral staircase, National Museum of Singapore (1887), and riveted mild steel balustrade, 1920s colonial government quarter.*

Above: *Art Deco metalwork balustrade, Raffles College (1928).* ***Left***: *Brass and bronze door accessories.* ***Far left***: *Stamped metal panel dado, St Joseph's Institution (1910s).*

Back to previous view

Common Deterioration, Causes and Diagnostics

Refer to *Chapter 1 'Introduction', section on 'General Notes on Common Issues and Maintenance'* for more information on the key principles and systemic issues related to the deterioration and diagnosis of interior elements.

Refer also to *Volume 5 Doors and Windows, Chapter 3 'Metal' and Chapter 6 'Ironmongery'* for more information on the defects, causes and diagnostics of non-structural metal elements.

Aside from regular maintenance inspection, detailed condition assessment should be carried out prior to any extensive repair and restoration works. A visual and tactile survey provides a quick overview, audit and mapping of quantities, location, material and condition of these historic interior elements.

VISUAL AND TACTILE SURVEY

For metal elements, the **extent of damage** and **dimensional loss** of material should be determined. Coatings, rust or other metal oxides of affected areas should be removed for proper assessment of the damage and any necessary dimensional measurement.

It is important to note that weathering and deterioration may be inconsistent depending on the design, construction and exposure of the element to wear and tear. Elements subjected to excessive handling, moisture exposure, or partial exposure to the exterior, as well as those with fine details and sections, are prone to more damage.

Common mechanical defects may include **deformation** from impact or overloading, **jamming** of operable or movable parts such as for hinges or electrical fittings, **dislodgement** or **missing parts**.

Right: *Stamped metal dado panel rusting along the edges.* ***Far right***: *Panel has completely rusted on the back, which faces the humid, under-ventilated roof space.*

Back to previous view

Common material defects for metals include **tarnishing** and **oxidation** – chemical reactions caused by exposure to the atmosphere, moisture, strong acid and alkaline solution. Left unchecked, oxidation will lead to **corrosion**, especially for ferrous metals where a layer of scale or rough surface is formed.

Iron oxide is usually reddish brown, while zinc and aluminium oxides are whitish. Copper-based elements (such as brass and bronze) oxidize when exposed to the environment, forming a layer of green patina that changes the hue and colour. Aluminium elements are usually pre-anodized; however, corrosion may still occur under certain circumstances such as presence of strong chemicals, damage or galvanic corrosion.

Contributing factors to the deterioration of historic interior metal elements include:

- Introduction of air conditioning that leads to condensation.
- Exposure to humid atmosphere from lack of ventilation, e.g., metal ceiling panelling with its back exposed to unventilated roof space.
- Installation methods such as joints and fixing points that tend to trap moisture and undergo crevice and galvanic corrosion.
- Components that are frequently handled, such as doorknobs, may have their coatings wear off and become discoloured.
- Inappropriate or inadequate maintenance, such as overpainting without rust removal, lack of regular oiling and polishing/waxing, and part replacement using a different metal causing bimetallic corrosion.

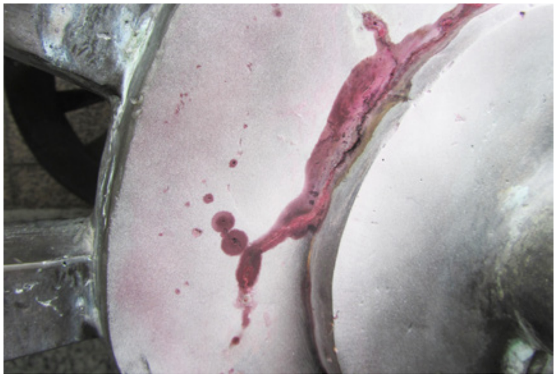
***From left**: Pitting on bronze casting; brass door handle tarnished due to wear and tear; bronze toplight grille oxidized from humid enviroment.*

NON-DESTRUCTIVE AND SEMI-DESTRUCTIVE TECHNIQUES

Non-destructive examination methods allow for on-site study of the elements.

- **Dye penetrant and magnetic particle tests** may be carried out to detect cracks and shallow abnormalities. At-risk locations where cracks are observed may be selected for testing.
- Laboratory or portable **XRF (X-ray fluorescence)** can be used to detect elemental composition for identifying the metal type.

During diagnosis and assessment, it is important that the specialist consider the method of conservation. Unlike the building, certain metal parts may be repaired on site while others can only be carried out off site as special containment or chemistry may be required.



Dye penetrant test highlights presence of cracks and pitting on metal.

Portable XRF used for in situ elemental identification.

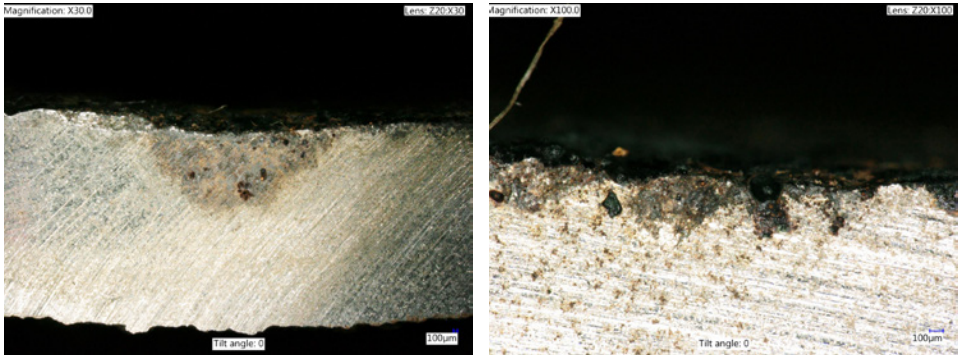
Back to previous view

SAMPLING AND LABORATORY ANALYSIS

Where elements are still in good condition, it is not necessary to do any destructive analysis. Where samples of damaged or dislodged materials are available, laboratory examination and testing of materials may be carried out to provide more accurate and in-depth analysis of the deterioration.

- **Microscopic analysis** is used for close examination of the material and coating. The number of samples and points to be extracted is to be determined by a conservation material specialist according to the optimal quantity and locations for comprehensive diagnostic results.
- **Paint stratification, pigment composition analysis** and other **coating investigations** may be carried out for where the interior metal elements are historically finished with **coatings or paintwork**. This will inform subsequent conservation methods and materials, as well as the post-restoration maintenance protocol.
- **Structural assessment** may be necessary depending on the type, function and construction of the historic metal element (e.g. metal staircase support).
- **Other** measurements though less significant for architectural elements may be carried out such as hardness tests, impact resistance tensile tests and material identification using X-ray spectroscope.

Refer to Volume 7 Paints and Coatings for more information on this topic.



Microscopic examination of metal showing surface corrosion.

Back to previous view

Conservation, Intervention and Maintenance

Refer to *Chapter 1 'Introduction', section on 'General Notes on Conservation and Intervention'*, for more information on the key principles and considerations related to conservation and intervention works.

Refer also to *Volume 5 Doors and Windows, Chapter 3 'Metal' and Chapter 6 'Ironmongery'* for more information on the conservation intervention of non-structural metal elements.

To determine the conservation method and approach, it is important to identify the type of metal and extent of defects. **Ferrous and non-ferrous metals** should be treated differently. Where metal condition is still good, surface cleaning should suffice. However, where there are defects on the coating or metal, the coating may need to be removed prior to maintenance repair. Deciding on **in situ or off-site restoration** would have different implications on intervention methods, storage, and protection considerations. For elements with complex form and multiple components, where ascertained that dismantling will not cause damage, it may be better to disassemble and service each part off-site.

CLEANING

For regular maintenance, **surface wiping** to remove dust and oil, with **scheduled waxing/polishing/oiling** (for moving joints) where applicable, usually suffice. This will prevent the built-up of dirt and grime, which tend to absorb and retain moisture. The use of strong alkaline or acidic solution, as well as excessive moisture, should be avoided. Soft fabric and sponge may be used for wiping. Scouring pads and wire brushes should be avoided as these will scratch the surface, damaging the protective surface layer. Even for deep cleaning, high-pressure mechanical methods such as pressurized water jet, mechanical brushing or sandblasting should be avoided.

Interior **copper-based elements**, such as bronze and brass items, should only be surface-cleaned to removed dirt. **Diluted non-ionic detergent** may be used when deeper cleaning is necessary, and the surface should be rinsed afterwards. This may be followed by waxing for a protective finish.

Protection of the choir loft cast-iron columns during construction stage, Cathedral of the Good Shepherd. In situ restoration of interior elements usually takes place towards the end of construction – in the meantime these elements should be well protected against accidental impact on the work site.

CORROSION AND COATING REMOVAL

Generally, removal of existing coating and corrosion is to be carried out during conservation of metal, to remove deleterious materials as well as prepare the surface for subsequent treatment. Such operations should only be carried out by skilled tradesmen or specialists, especially for interior feature elements with intricate detailing.

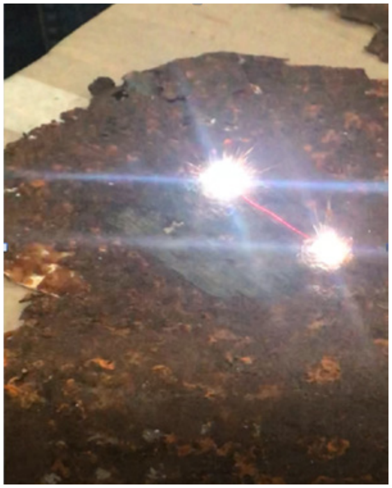
- **Soft wire brush and sandpaper**: For iron elements, even minor rust spots should be treated as the surface corrosion may propagate, causing loss in material integrity, besides affecting the appearance of the element. **Localized rust** may be removed by careful use of a soft wire brush and sandpaper, following which the surface may be recoated or repainted for protection.
- **Chemical cleaning**: For **stubborn residues**, chemical cleaning may be more effective for removal of worn-out paint and corrosion. To minimize environmental pollution, non-toxic, biodegradable and odour-free paint-stripping chemical systems should be used.
- **Flame cleaning** may be used for loosening corrosion and softening paint on wrought iron, before the residue is brushed off.


Trial paint removal of a metal ceiling panel using odour-free non-toxic biodegradable chemical stripper.

Back to previous view

The fine details of the relief revealed, after removing multiple layers of coating from the overpainted baluster.

- **Sandblasting**: For **severe corrosion** of iron elements, including cast and wrought iron, wet and dry sandblasting with an appropriate blasting medium may be used. Inert mineral grit, glass beads and walnut husks are examples of media that can be used for iron-based material. The proper blasting pressure, nozzle type and technique are important to ensure optimum removal of corrosion residue without damaging the parent material. This method is mainly suited for factory restoration due to regulatory requirements for proper containment and removal of debris. Approval will need to be sought from the relevant authority if this operation is to be carried out on-site.
- **Copper-based elements**: Stubborn stains may be cleaned with low-pressure water cleaning with non-ionic pH neutral soap, followed by rinsing. Previous coatings may be removed by pressurized steam cleaning. Surfaces should be waxed after cleaning for protection. Corrosion inhibitor such as benzotriazole (BTA) may be applied prior to waxing to increase protection.
- **Specialist methods** of coating and rust removal that are gentle yet effective, and particularly suited for intricate metal interior elements, include **laser cleaning** and **dry ice blasting**.



*Coating and rust removal using specialist laser (**left**) and dry ice (**right**) methods.*

Back to previous view

JOINING (COLD REPAIR, WELDING, SOLDERING)

After surface cleaning and corrosion removal, any necessary repair works may be carried out, usually with a combination of various methods depending on the material, defects, construction, access, safety and other issues. Care should be taken in the selection of repair materials and fasteners to prevent bimetallic corrosion. Metal repair work calls for specialist workmen and equipment.

- **Cold repair** work is particularly suitable as it can be carried out on-site and there is less risk of thermal or mechanical damage. Fastening by **bolting, stitching and plating** are typical cold repair methods. Recent technical advancements include using **non-metallic cold repair methods** such as epoxy adhesive for non-structural minor repairs. Fillers and fibres may be added to the epoxy to provide improved strength and match the texture.
- **Hot repair** methods include **brazing, soldering and welding**. For brazing, often used for repairing bronze elements, a molten filler is introduced to the heated metal parts to be joined. Soldering is similar to brazing, except that the filler used is of a lower melting point and applied to ferrous metals. Various types of welding methods are also used for the repair of ferrous metals.

Hot repair of crack by welding.

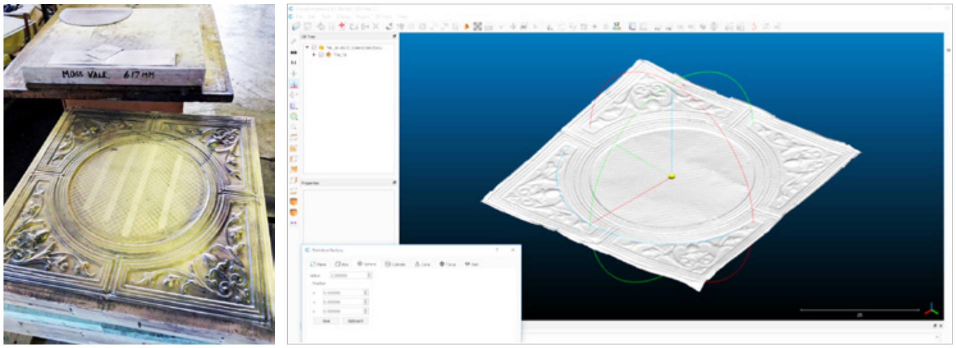
Back to previous view

Cast-iron unicorn motif 3D test print replica using metal powder as printing medium, produced from 3D scanning data.

LOCALIZED REPLACEMENT AND REINSTATEMENT

Where components are damaged beyond repair or missing, localized replacement may be carried out. Common metal parts or prefabricated catalogue-order units may be sourced from material suppliers or salvage yards.

The reinstatement of bespoke or less common components may call for **small-scale replica fabrication**. Traditionally the replica would be crafted from scratch, or a hand-made mould would be modelled on an existing component, based on a measured drawing, and used to cast the parts. The results depended heavily on the workmanship of the fine metalwork foundry. More recently, **3D scanning, photogrammetry and 3D printing** have enabled more efficient and accurate replicas that can overcome the problem of unsatisfactory workmanship and the high cost of small-scale factory production.



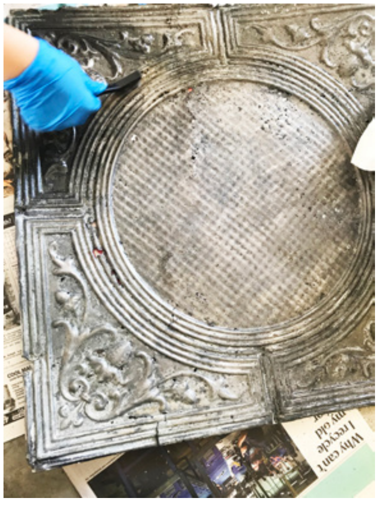
Following paint and rust removal, a high-resolution 3D scan is carried out and used for creating a mould to manufacture replicas.

Refer to *Volume 7 Paints and Coatings* for more information on this topic.

PROTECTIVE COATING

Typically, protective coating is applied after repair and may be reapplied as part of regular maintenance.

- Most modern **paints** used for iron-based metals comprise a three-layer system. The first layer is a primer, often a zinc or aluminium-rich primer that gives adhesion and corrosion inhibition properties to the surface. The second coat provides the thickness, durability and opacity of colour, while the final coat gives colour and texture. Common paints for metals include polyurethane, epoxy, acrylated-rubber and alkyd-based systems. It is common to repaint metal above the existing layer provided the paints are compatible. However, after several coats of overpainting, the details and features of the metal may be obscured, and paint stripping should be done.
- **Waxing** for copper-based metal can be carried out using microcrystalline wax. The wax may be made liquid by heating as this will soften and penetrate the porous patina layer. Care is to be taken to prevent overheating of the metal. Two or three layers may be required to ensure adequate coverage. The wax layer should last for two to three years with minimum handling and contact. For elements that are frequently touched and handled, the wax layer tends to wear off in a shorter time, followed by tarnishing. However, this does not normally cause any long-term damage to the surface.



Trial application of coating on mild steel stamped metal ceiling panel with paint removed, beginning with a primer.

4 IN SITU, PRECAST AND TILE FINISHES

Back to previous view

Overview: In Situ and Precast Finishes

Refer to *Volume 3 Facades, Chapter 2 'Plasterwork'*, for more information on the history, production and application of plasterwork.

Interior hard surface in situ finishes such as plasterwork, terrazzo and cement are premixed or site-mixed and manually worked, before being left to cure and harden.

PLASTERWORK

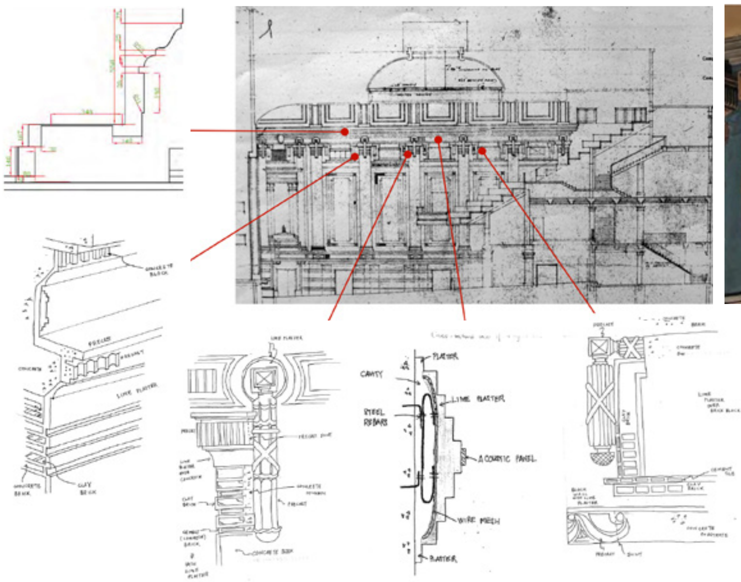
Interior ornamental plasterwork generally comprises ceiling cornices, wall dadoes, skirtings, door and window architraves, and column capitals. Due to the high degree of **artisanship** required, this is more commonly found in civic and commercial buildings, as well as more well-endowed historic residences. These details are present in critical **junctions** between building components – such as the junctions between horizontal (ceiling) and vertical (wall) elements, fulfilling both an aesthetic and functional requirement.

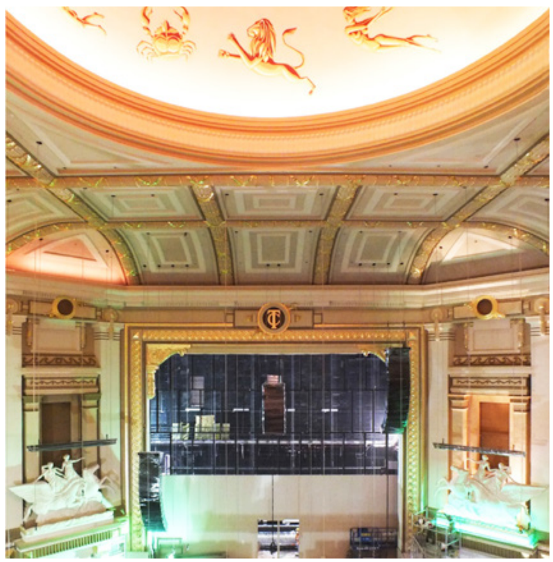
Their overall composition and construction methods are largely similar to exterior ornamental plasterwork, with some differences in materials. An example is **Madras chunam** – a polished, self-finishing lime plaster with additives of egg white, jaggery and coconut husk fibres. While these additives greatly improved workability and gave rise to a highly finished appearance, it also meant that internal plasterwork was generally more vulnerable to moisture damage. There is no extant local example today. Other additives found include gypsum and cellulose pulp.

Stately atrium of Raffles Hotel with architectural elements accented by ornamental plasterwork.

Interior ornamental plasterwork reached a pinnacle of artisanry and craftsmanship in the early 1930s, with the completion of the **Capitol Theatre**. Touted as the largest picture palace in Malaya, the cavernous theatre hall featured elaborate **precast** proscenium and ceiling ornaments, wall panelling, architraves and other mouldings. Some of these actually served as 'permanent formwork' for casting secondary structural beams. By the postwar decades, however, with the advent of mass fabrication and high costs of labour-intensive building trades, ornamented plasterwork went into decline.

Today, intact historic internal ornamental plasterwork is increasingly rare and should be safeguarded as precious testimony of Singapore's building craft traditions.





__Above__: Interior ornamentation of the Capitol Theatre, showing construction details. __Above right and far right__: Precast RC ornaments, as found on site – reed bunch motifs flanking the clerestories and 'cascading coin' medallions framing the proscenium. __Right__: Restored historic interiors of Capitol Theatre.

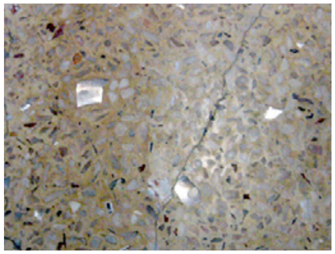
IN SITU TERRAZZO

Durable and easy to maintain, terrazzo offers wide-ranging colours and textures, all at a fraction of the cost of natural stone. In situ terrazzo is considered the 'original' construction technique that predated prefabricated terrazzo tiles and architectural components. Built in layers, the top decorative finish is a thin layer comprising marble **chipping aggregates** mixed in a coloured **cement binder**, and rests on a thick **cement screed base**. It is ground to a smooth finish after it has set.

Well-executed in situ terrazzo requires considerably higher **artisanship** in the mixing, compacting and laying process, compared to factory-made tile units. The fluidity of in situ terrazzo beautifully expresses curvilinear architectural elements such as staircase stringers, parapets and round columns, while precast terrazzo units were employed for floor and wall tiles. The Supreme Court of 1939 (now National Gallery) is a dazzling showcase of precast fluted columns set against in situ dadoes and flooring, impeccably executed by the studio of Italian sculptor and specialist **Cav. Rodolfo Nolli**.

Postwar terrazzo surfaces and units were well mixed, compacted, and free of air bubbles, resulting in a high-quality finish that was the rage from the 1950s till the 1970s.

Below: *Terrazzo flooring featuring large aggregates.* ***Bottom***: *Precast terrazzo balustrade found at the Capitol Theatre.*



Above left: *Full-height in situ terrazzo dadoes and precast terrazzo columns line the second-storey courtroom passageways of the former Supreme Court.* ***Top right***: *Mother-of-pearl chipping is introduced as accents on the wall dado.* ***Above right***: *Impeccably crafted fluted column in terrazzo.*

In Situ and Precast Finishes

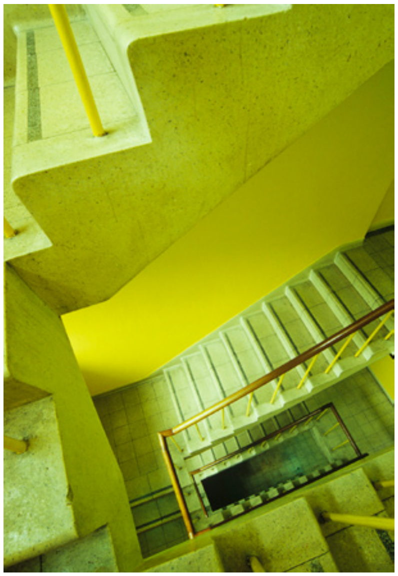
Grand atrium of former Supreme Court, with restored ornamented plaster and terrazzo elements.

Richly ornamented interior of prayer hall, Abdul Gafoor Mosque.

__Right__: Crisp terrazzo staircase at former Institute of Health. __Far right from top__: Sinuous terrazzo parapet and stairs at Nassim Hill Flats; terrazzo column and precast tiles at Nanyang Pho Leng Hui Kuan.

Deteriorated in situ decorative plaster dadoes, historic townhouses.

Interior cornice moulding and column capital with Art Deco motif in residences.



Back to previous view

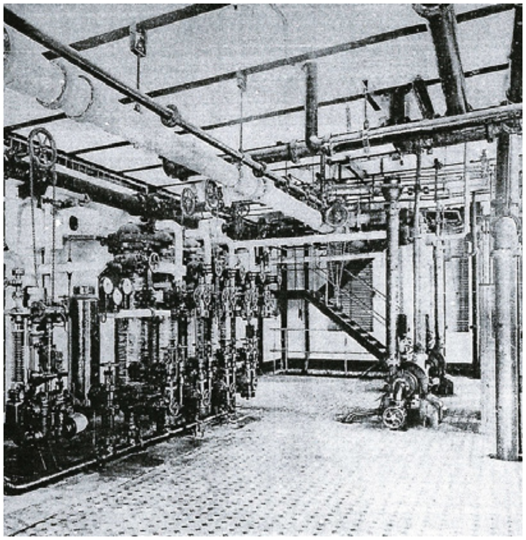
Overview: Tile Finishes

Refer to Volume 3 Facades, Chapter 5 'Ceramic Tiling' and Chapter 6 'Cladding', section on 'Stone Cladding', for more information on the history, production and application of clay-based and stone tiles.

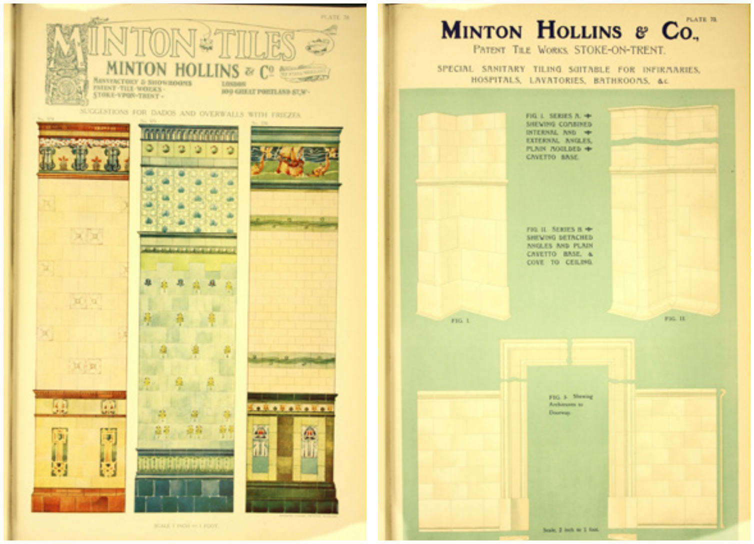
Another main category of interior hard surface finishes comes in the form of prefabricated or manufactured modular-size tiles or panels which are laid with cement or lime-based bedding adhesive. These include **clay-based (ceramic)**, **cement-based** and **stone** tiles.

CLAY-BASED (CERAMIC) TILES

Ceramic tiles refer to a wide-ranging family of clay-based tiles, encompassing sub-varieties such as terracotta tiles, quarry tiles, encaustic tiles, porcelain tiles and tin-glazed decorative tiles to the beautiful hand-painted glazed tiles adorning the Singapore Railway Terminus. Some types are available in both **unglazed** and **glazed** finishes. They were widely used for **floor and wall coverings**, and can be found in historic bungalows, terraced townhouses and shophouses, as well as civic buildings and religious monuments.



View of a plant room at the St James Power Station with Minton-manufactured ceramic wall and floor tiles, specified for their sanitary quality, resistance and durability.



*Pages from a tile catalogue produced by major British manufacturer Minton, Hollins & Co. Its wide-ranging products – from the highly decorative (**left**) to specialized use (**right)** – were marketed and shipped globally, including to Singapore and Malaya.*

Back to previous view

Early terracotta tiles are usually laid with wide mortar joints to accomodate the slight variations in size and uneven surfaces that give the finish a rustic appearance. Meanwhile, industrial manufactured quarry tiles with no shrinkage issues are standardised in dimensions, enabling tight joints.

An early ceramic product dating to prehistory, **terracotta tiles** are commonly found in utility areas in prewar buildings, such as in kitchens, storerooms, courtyards and semi-outdoor patios. Traditionally these were pressed in wooden moulds and kiln-fired at a relatively low temperature, yielding porous tiles with uneven hues of red from the iron in the clay. The tonality varies from salmon-pink to burgundy red, depending on the provenance of the raw clay and the firing temperature. Terracotta tiles may also be glazed to create a more impervious surface. **Quarry tiles**, fired at a much higher temperature in a process similar to brick-making, is a much denser and more impervious material. In the postwar years it is commonly used in front-of-house areas, such as verandahs and living rooms of government civil service housing.

Manufactured and imported from England, France, Belgium and later Japan, **tin-glazed ceramic tiles** were popularly used for ornamented wall dadoes. They are commonly found adorning the facades and interior walls of prewar historic townhouses belonging to Straits Chinese families, and by association, colloquially known as 'Peranakan tiles'. **Porcelain tiles**, also belonging to the ceramic family, is particularly known for being impervious to water, and commonly used for wet areas such as bathrooms and kitchens.

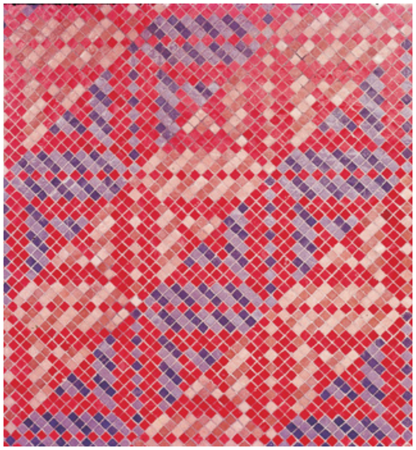
Left & middle: *Salmon-pink prewar terracotta tiles are usually underfired, porous, with wide mortar joints; postwar quarry tiles are dense, fired at high temperature, and evenly sized with tight mortar joints.* ***Right***: *Porcelain tile dado capped with moulded dado rail tiles at the former Singapore Railway Terminus.*

Back to previous view

Ceramic mosaic tiling became popular during the postwar decades when industrialization democratized the once labour-intensive and costly building craft, appearing in myriad building types including residences, schools, religious buildings and entertainment complexes. The colourful, characteristically **small modular size** of mosaic tiles also possessed an innate ability to enhance human scale and provide visual relief in kaleidoscopic permutations — random mix, chequerboard, bands and geometric shapes. Moreover, mosaic proved to be highly suitable in negotiating the undulating contours and surfaces characteristic of reinforced concrete construction. These characteristics were exploited by modernist architects who abhorred overt ornamentation, greatly enlivening the interiors of numerous civic monuments, most notably the former Singapore Conference Hall and Trade Union House. By the 1970s, coinciding with the rise of avant-garde cultural movements such as pop art, mosaic gained an iconic status that resonated with the times.

Top row from left: *Lozenge-shaped mosaics installed onto the curvilinear entrance wall to the cinema hall of The Metropole; Main staircase in Nanyang Pho Leng Hui Kuan featuring mosaic tiles in 'pinwheel' configuration.*

Bottom row from left: *Feature wall using mosaic to recreate a traditional 'Meng Kuang' weave pattern, former Singapore Conference Hall (1965); Bichromatic mosaic flooring at the Church of St Bernadette, a delightful reinterpretation of the traditional chequered stone tile arrangement.*



THE MURAL TILE ARTWORK OF TANJONG PAGAR RAILWAY STATION

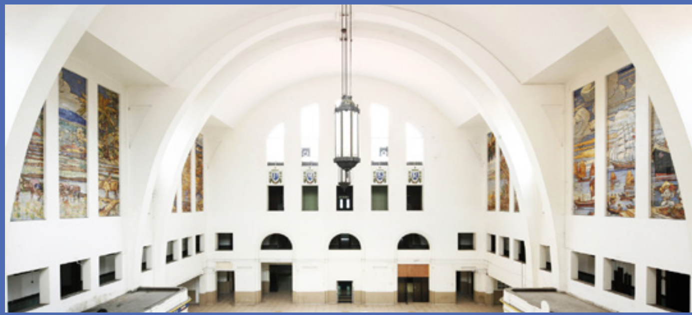
Two of the triptychs depicting a rubber plantation *(left)* ***and a seaport with types of sea vessels*** *(right)**.***

Six massive triptych panels in glazed terracotta tiles line the east and west faces of the Passenger Hall atrium of the Tanjong Pagar Railway Station. As reported during its opening day in 1932, "[…] vividly painted, they catch the eye of the visitor, and command his admiration…" The hand-painted mural panels depict scenes of primary means of transport, agriculture and industries and represent the multi-ethnic communities in Malaya.

The artwork was believed to be a collaboration between artist William Rowe (1882-1939) from the major UK manufactuer **Doulton Company** and architect Denis Santry (1879-1960) from Swan and Maclaren.

Denis Santry, who joined Swan and Maclaren between 1918 and 1934, worked on many public buildings undertaken by the firm. He was known to be an architect with a strong flair for painting and designing cartoons.

During the First World War, some of his war cartoon illustrations were published in book collections. The painting could have been possibly done with sketches by Denis Santry himself, which were then sent to William Rowe for detailed composition on terracotta tiles.



The specially commissioned handpainted ceramic tile mural art comprises six triptych panels adorning the main hall of Tanjong Pagar Railway Station.

The manufacturing process likely started with freehand painting on plain white tiles and glazed before being fired by experienced kiln stokers. W.J. Neatby, who served as head of Doulton architectural department from 1890 to 1907, perfected several novel techniques of glazing and colouring ceramic tiles, including the creation of a matt surface terracotta after firing such that the overall effect was that of a fresco. This was important because the decorative mural artworks had to be impressive for the Station Passenger Hall, well coloured yet at the same time not too reflective when lit by natural light from the clerestory windows.

Close-up inspection reveals expressive brushwork, bold use of colours, sensitive gradations and various stippling techniques, imparting depth and vibrancy to the mural artwork. There appear to be a few base colours for the tiles depending on the scenery backdrop - e.g., sky, sea, vegetation, earth, etc., which are then overpainted to create the artwork. It is likely that accents were once used to highlight certain features, through the use of special enamelled (metallic) paint on the completed work. Traces of slightly reflective overpainting are discernable, though these are now dulled and faded due to age or inappropriate maintenance cleaning in the past.

Views showing hand-painted detail of a locomotive *(left)* ***and the rich chromatic range of clouds in a sunset scene*** *(middle)****. Original gold accents such as the wing tips of the bird have since tarnished*** *(right)****.***

Back to previous view

ENCAUSTIC TILES

Encaustic tiles are ceramic tiles with an inlaid pattern that is made up of different coloured clay, from two to as many as six colours. The clay is individually filled into cavities of the steel pattern moulds, pressed, and then fired. This innovation in tile manufacturing meant that encaustic tiles are much more durable and colourfast than traditional ceramic tiles whose patterns are formed using coloured glazes.

A leading manufacturer and exporter of 'modern' encaustic tiles in the UK was **Minton, Hollins & Co.**, whose founder adopted and combined industrial production of inlaid tiles and the 'dust-press' technique, to facilitate large volume manufacturing, greatly reducing production time and costs. As a result, these tiles quickly gained popularity and proliferated across the British colonial empire, exemplifying a success story of the Industrial Revolution. Known for their design versatility and quality, Minton tiles were specified for prestigious projects such as the Westminister Palace and Victoria and Albert Museum, UK, and the Capitol building in Washington, DC.

Locally, prominent buildings that featured Minton encaustic tiles include: Raffles Museum and Library (now National Museum of Singapore), former St Joseph's Institution (present-day Singapore Art Museum), and the Raffles Hotel Bar and Billiard Room. However, many of these were replaced during latter-day renovations. Today, only a handful of existing historic bungalows built between the 1900s and 1920s feature these rare tiles in a domestic setting.

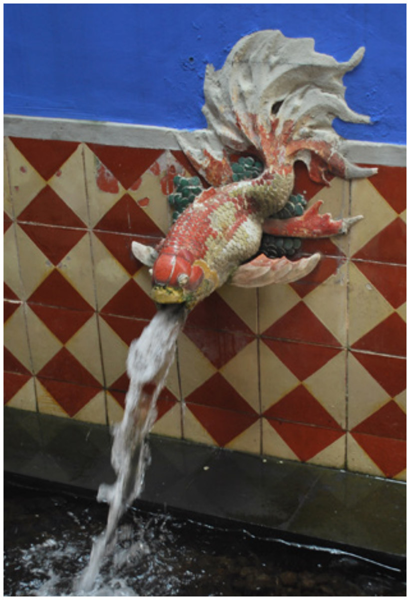
Left: ***Minton product catalogue featuring bichromatic and polychromatic encaustic tile in a wide variety of designs and patterns.*** *Above*: ***The manufacturer's imprint can be seen on the reverse side of the tile, as a mark of its authenticity.***

Notably, a number of colonial government quarters feature bichromatic black and white geometric designs. The light-coloured field tiles are usually laid in a diagonal grid, with pronounced black accents forming a contrasting inlay pattern. Sometimes, intricate border tile patterns are created using smaller units, clearly defining each interior space by lining the periphery. This contrasting, geometric design was in line with the Gothic Revival movement in Victorian England, recreating Gothic bichromatic stone paving patterns using encaustic tiles. On the other hand, polychromatic encaustic tiles can be found in larger, more prominent residences as well as public buildings. Their design and materiality gives a rich, stately character that complements the elegant proportions of their architectural interiors.

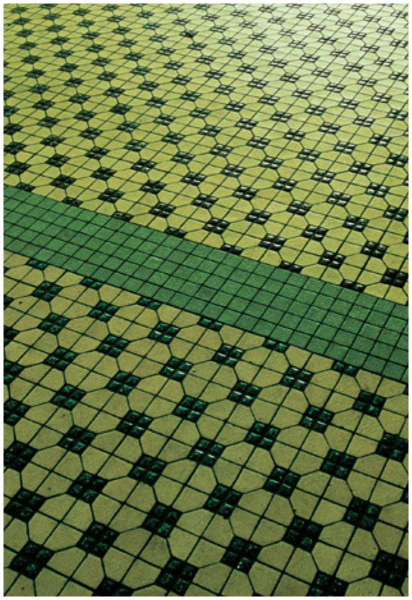
Painstakingly restored bichromatic encaustic tiles at 126 St Patrick's Road, now refurbished as a condominium clubhouse. The historic floor finish adds much heritage character and authenticity to the development.

Example of polychromatic encaustic tiles used in the dining room of a colonial bungalow, testifying to the wealth and status of its former occupants.

Clay-based (Ceramic) Tiles



***Clockwise from left**: Geometric pattern encaustic floor tiles at Beaulieu House (1910s); A dado of glazed terracotta tiles, and waterspout shaped as a fish, clad in 'scales' of glazed ceramic shardwork, in a historic townhouse (1890s); Porcelain dado tiles laid in flemish bond pattern, with curved corner units, military drill hall (1930s); Flooring design composed of plain and ornamental encaustic tiles.*

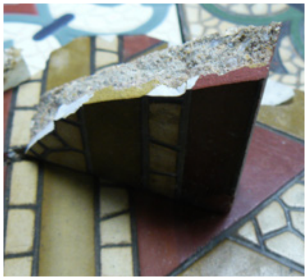


***Left to right**: Mosaic flooring accented with a grid of motifs, Church of St Bernadette (1959); Mosaic tiles with a raised embossed centre add visual texture and slip resistance, house at East Coast Road (1950s); Small mosaic tiles are used to wrap around curved surfaces such as this circular column in the Cundhi Gong Temple.*

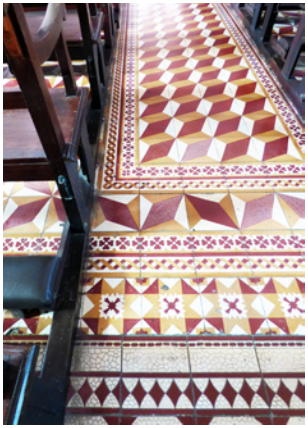
CEMENT-BASED TILES

Although early **polychromatic cement tiles** adopted the design and patterns of encaustic ceramic tiles, they are of very different materials and manufacturing process. The top finishing layer comprises white cement with colour pigments added into the different compartments of the steel 'cloisonne moulds'. This was then removed, with grey **Portland cement** filling the rest of the tile body. The tile was then hydraulically pressed together and left to cure, without any need for kiln firing as in the case of encaustic tiles. This technique, patented in France in the 1850s, greatly reduced manufacturing costs. Touted as a durable, affordable and attractive product, cement tiles enjoyed widespread popularity not just in Europe but also in its colonies, notably in French Indochina and Morocco.

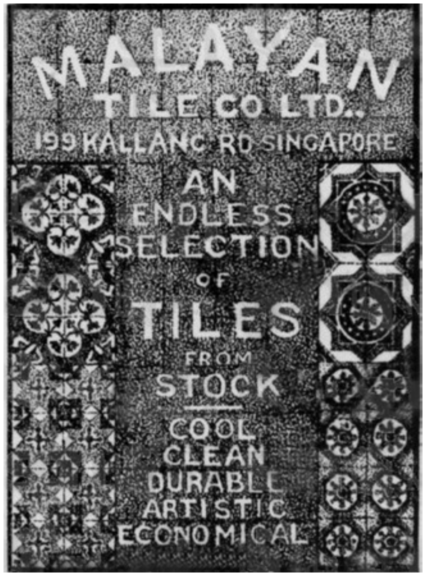
In Singapore, cement tiles were both imported as well as manufactured locally, such as by the Tampenis Cement Tile Works located at Sungei Road, Rochor. In operation till the 1950s, in its heyday it produced 2,000 pieces daily and exported them to Malaya and Indonesia. Today, these heritage artefacts of the early 20th century can be admired in religious monuments such as the Church of the Nativity of the Blessed Virgin Mary, former Tanjong Pagar Railway Station, old St Joseph's Institution, as well as the Rectory of the Cathedral of the Good Shepherd.



Polychromatic cement tile fragment showing pigmented finishing layer on a 'body' of grey Portland cement. Grooved imprints are added for slip resistance.

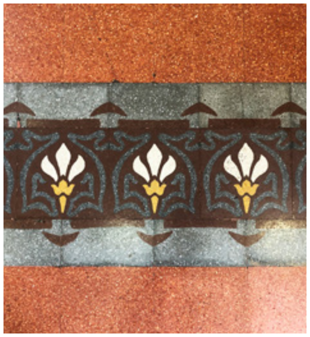


Cement tiles of a myriad of colours and geometric motifs line the nave of the Church of the Nativity of the Blessed Virgin Mary.



By the 1930s, cement tile manufacturing had taken off successfully in Singapore, adapting the French technology to the local context and market.

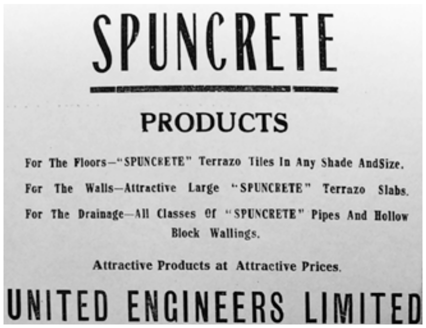
Back to previous view

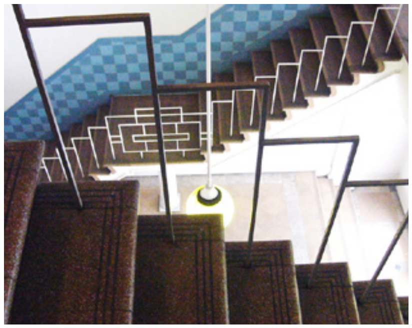


Terrazzo tile as the medium for Art Nouveau design featuring vibrant, contrasting colours and organic stylized forms.

Terrazzo flooring has a long history in Europe, particularly in Italy, where it originated from a Veneto region building craft, *terrazzo alla veneziana*. It is described as 'concrete in which marble chippings are used as aggregates and which is ground to a smooth surface; generally used as a floor topping or in the form of precast slabs for wall lining, partitions, and similar purposes'. **Precast terrazzo tiles** were a popular material in Singapore from the interwar decades right up to the early 1970s: it is extremely durable and low maintenance, offering design versatility and wide-ranging colours and textures at a fraction of the cost of natural stone tiles. One of the earliest examples of its use in a civic building is the Clifford Pier.

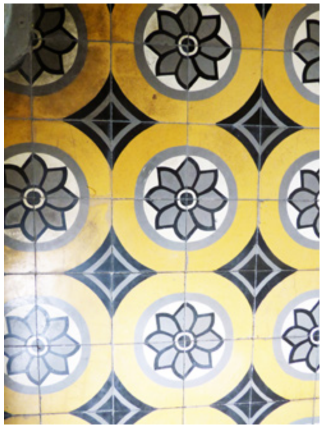
United Engineers developed and manufactured a local variation – '**Spuncrete**' terrazzo tiles. They are used in the old Supreme Court, laid in several sophisticated geometric patterns, which remains a rare surviving example of their early use. The trade name 'Spuncrete' was an acknowledgement of the manufacturing process – a then cutting-edge technology of concrete compaction by centrifugal force – thus the word 'spun' – used previously in the manufacture of concrete pipes and poles. Terrazzo tiles remained popular as an interior finish in community and domestic settings till the 1980s.





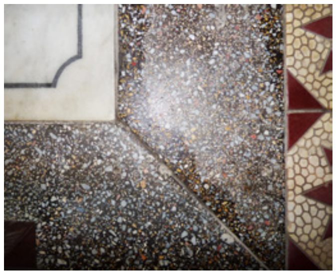
***Left**: Advertisement for 'Spuncrete' terrazzo products, a local innovation by the firm United Engineers Ltd. **Middle**: The old Clifford Pier was one of the earliest civic buildings in Singapore to use large slabs of 'Spuncrete' terrazzo flooring for its hard-wearing surface, ease of maintenance and attractive appearance. **Right**: Detail of precast terrazzo staircase treads at the former Supreme Court building. The side walls are lined with ceramic dadoes.*

Cement-based Tiles



Left: *Historic polychromatic cement tiles of unusually wide ranging patterns, possibly donated, Rectory (1911) of the Cathedral of the Good Shepherd.* ***Above left and right***: *Church of the Nativity of the Blessed Virgin Mary (1901).*

Above left: *Black and white precast 'spuncrete' terrazzo tiles laid in checkerboard pattern, with special curved riser and grooved step riser units, likely custom-produced for the former Supreme Court (1939).*
Above middle: *Crimson terrazzo field tiles impeccably matched with Art Nouveau border tiles, Beaulieu House (1910s).*
Above right: *Floral terrazzo in vibrant colours with a border of bichromatic cement tiles, shophouse at Syed Alwi Road.*
Right: *Detail view of terrazzo tile with multicolour aggregates forming the border of a marble floor plaque, Church of the Nativity of the Blessed Virgin Mary (1901).*

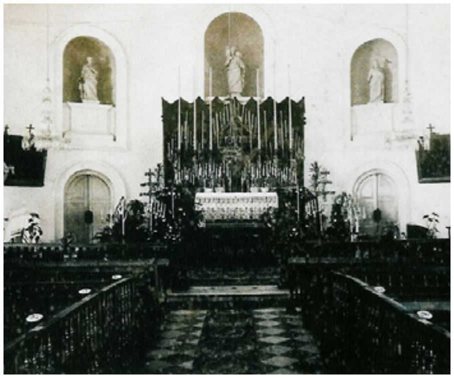


Back to previous view

STONE TILES

Historic interior finishes in natural stone are relatively uncommon due to the high material, workmanship and installation costs. As a result, stone-clad or paved interiors are mostly found in major religious, commercial and civic buildings. The most common types of stone used as interior finish in Singapore are **marble** and **granite**, and to a lesser extent, limestone and slate. Strong and hard-wearing granite are used as door thresholds, starter treads of staircases, and airwell pavers in traditional shophouses. These were mainly from **local granite quarries** at Pulau Ubin and Bukit Timah, although some were imported from Europe and China.

On the other hand, marble was deployed as a high end interior finish reserved for select residences and prominent public buildings. Until the early 20th century, this was mainly **imported** from Italy, notably *Marmo di Carrara*, prized for its gleaming white appearance given by its tonal homogeneity and translucent surface after polishing. Examples of its use include the flooring of Armenian Church (1835), Cathedral of the Good Shepherd (1847), and the renown Raffles Hotel main building (1899). Other notable prewar examples of the use of imported marble include the 1928 Municipal Building (later City Hall and now National Gallery of Singapore), as seen in the Art Deco 'grey and white' dadoes and flooring and the colossal columns flanking the Muncipal Boardroom (the site of the Japanese surrender in 1945). It would also not be difficult to imagine the marble-lined banking halls in the mercantile buildings lining Raffles Quay, demolished in the 1960s.



*The original marble flooring at the Cathedral of the Good Shepherd, part of which can be seen in the archival photograph (**right**), was fully revealed after the latter-day mosaic flooring was removed (**left**). The marble tiles are one inch thick (**top**).*

Luxurious yet understated, large slabs of Carrara marble are used for the grand stairhall of the former City Hall (now National Gallery Singapore).

Back to previous view

Due to a very high rate of breakage during overseas transport, and increasing difficulty in procurement after WWI, **locally quarried marble** from Malaya emerged as a viable alternative that though more limited in variety was much more affordable. In particular, **Ipoh Marble Works**, founded in 1914 by Jacob Von Ravensway and James Berry, was touted as 'the only marble works in the East', claiming to be 'the best in the world for flooring purposes, graves and tombstones, and for table tops'. The marble quarried was 'cut, polished and moulded by steam driven machinery of modern type'. In the 1920s marble quarries opened in Langkawi Island and their supplies became much sought after as well. It is likely that Malayan marble was used in colonial government housing.

Advancements in manufacturing processes during the post-WWII period led to marble becoming more affordable, and popularized its use in more building types. An outstanding example is the expansive Billiard and Games Room of the 1950s NAAFI Britannia Club (later NCO Club and now part of the South Beach development), which features unusual grey Sicilian Bardiglio Cappello marble dadoes. Innovative hybrid products such as 'Cocciame' flooring – which features broken Travertino stone bound to a cement base – are used in the Trinity Theological College chapel built in 1968.



Left: *Bichromatic stone flooring along the main hallway of a historic bungalow, comprising 'field' tiles in white Carrara marble, with border accents in dark green Serpentine marble.* ***Middle:*** *Book-matched Bardiglio Cappello marble dado in the former NAAFI Britannia Clubhouse (1953, aka NCO Club).* ***Right:*** *Detail of special Cocciame tiles comprising broken Travertino marble adhered onto a cement substrate, found in the former Trinity Theological College chapel (1969). The fragments are salvaged by-products of marble quarrying and cutting large blocks of natural stone.*

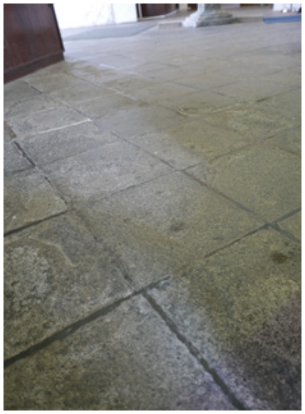
Back to previous view

Stone Tiles

The unusual Cocciame (broken Travertino) floor tiles in the Trinity Theological College chapel (1969), since restored.

Bianco Carrara marble flooring accentuates the soaring, stately atrium space of the Subordinate Courts building (1975).

Marble-clad feature columns, the former Japanese Surrender Chambers of the Singapore Municipal Building (1929, now National Gallery of Singapore).

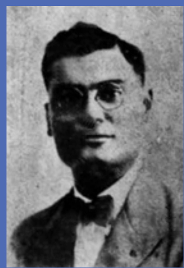


***Above left**: Marble flooring with dark green accents articulating the archways. **Above right**: Granite flooring, St. Andrew's Cathedral (1861). **Right**: Detail of Bardiglio Capello marble dado, with a darker skirting strip, at the restored NCO Clubhouse.*

Back to previous view

EXPERIMENTS IN RUBBER TILE AND CORK TILE

Left: ***Advertisement for Cressonite Rubber Tiles, a local innovation manufactured by the Singapore Rubber Works.*** *Below left:* ***Lionel Cresson (pictured right) was then its Chief Chemist.*** *Below right:* ***Flooring in Cressonite rubber in the former Supreme Court, mimicking bichromatic marble flooring. These have since been replaced during the building's conversion into the National Gallery of Singapore.***



RUBBER

Rubber as an architectural finishing material had already been in use since the 1900s. Following breakthroughs in its manufacturing processes where it became more stable and wear-resistant, it gained popularity in the mid-1920s, especially in the United States and England, a modern material lauded for its acoustical dampening effect, low maintenance, design versatility, and hygienic properties. Set in geometric patterns, it is an integral design element to the 1930s Art Deco architectural interiors.

One of the most underrated innovations in early local material engineering, "Cressonite" rubber tiles were widely featured in the Tanjong Pagar Railway Station (1932), purportedly the first use of these tiles in a building, as well as Kallang Airport (1937) and Supreme Court (1939). Developed by local-born Lionel Cresson – who became Chief Chemist of Singapore Rubber Works in the 1930s – these were manufactured using Malayan rubber that had fuelled the wealth of Singapore. The material told of Singapore's critical role as a global distribution centre for this sought-after commodity.

Rubber tile dado lining the corridors of the hotel at former Singapore Railway Terminus (1932, aka Tanjong Pagar Railway Station).

Left: ***Rubber tile dadoes and parapets complementing geometric Art Deco forms, former Singapore Railway Terminus (1932).*** *Right:* ***Cressonite rubber flooring mimicking bichromatic marble tiling, former Supreme Court (1939).***

Left: ***The former Chief Justice's Courtroom was paved in cork parquetry in checkered pattern, since removed after it had become dry and brittle over time.*** *Right:* ***Advertisement for imported cork flooring.***

Standard rubber tiles were homogeneous and thus costly; Cresson innovated a composite product where expensive rubber was only a thin layer of facing material sitting atop a base. It was selected by the colonial PWD architects due to its acoustic performance, economy and design versatility. To-date, the rubber tile dadoes at the Railway Station and St. Patrick's School Chapel are rare surviving evidence of the use of this historic local building material.

CORK

Cork comes from the outer bark of the cork oak, traditionally grown in the Mediterranean region. It is championed as a revolutionary material due to its good thermal and acoustic properties and the self-renewing abilities of the trees. Cork was widely used in the interwar period, first as heat and sound insulation, then as an architectural finish for its natural wood-tone, resistance to moisture, dirt, mild acids and stains. Attractive floor patterns can be achieved at a fraction of the cost of traditional timber parquetry. Cork was a favoured by Modernist masters such as Walter Gropius and Marcel Breuer. In Singapore, "Eldorado" cork parquetry is primarily used in the former Supreme Court, as well as the old Kallang Airport Terminal Building, taking the place of traditional timber parquetry to inject some warmth into otherwise austere interiors. Archival building plans and photographs reveal different tile arrangements, ranging from checkers, herringbone, to stretcher bond. Unfortunately these historic cork flooring have been replaced with latter-day homogeneous tiles.

Cork parquetry, passenger lounge, Singapore Aerodrome (1937, aka Kallang Airport).

Floor and Wall Substrates

Top: *Mock-up for ornamental plaster cornice showing masonry substrate build-up.* ***Above***: *Exposed brick and terracotta substrate underneath ornamented plasterwork, including the cornice and dentil.*

A variety of substrate materials could be used for interior finishes. **Wall finishes** could be installed on brickwork or cement block masonry, or on timber and other drywall construction. Tiled finishes were mainly fixed using bedding mortar, or mounted on a sub-frame fastened onto the wall. In situ ornamental plaster or terrazzo finishes would require a two-coat base render comprising a rough scratch coat (or 'splatter-dash') to provide sufficient mechanical key, followed by a coarse grain base coat. Sometimes, a metal lath would be added to the base coat to strengthen it prior to receiving thick or heavy architectural finishes. Both would need to be adequately cured before application of the fine grain finishing plaster or terrazzo.

On the other hand, substrate material for internal pavement and **floor finishes** generally comprised a compacted hardcore material (or ballast), followed by a fine sand layer known as 'blinding', upon which was cast a mass concrete which consisted of brick rubble, stone aggregates bound in a lime-based mortar. A coarse-grained lime- or cement-based screed would then be laid and trowelled to receive the final floor finish. Tiled finishes would generally require bedding mortar adhesive to be applied, prior to their installation.

Generally, the appearance of cracks and delamination of historic finishes are attributed to anomalies within the substrate. Limited break-outs should be carried out to assess the **substrate condition** and determine the likely causes of the surface deterioration. In most cases, substrate integration repairs will be necessary.

Layers of floor build-up can be clearly seen – finish layer, screed, sand blinding and compacted hardcore.

Back to previous view

Common Deterioration, Causes and Diagnostics

Refer to Chapter 1 'Introduction', section on 'General Notes on Common Issues and Maintenance' for more information on the key principles and systemic problems related to deterioration and maintenance.
Refer to Volume 3 Facades, Chapter 2 'Plasterwork', Chapter 5 'Ceramic Tiling' and Chapter 6 'Cladding', section on Stone Cladding for more information on the deterioration and diagnostics of plasterwork as well as stone and clay-based tiles.

Ceramic tile debonded from bedding.

VISUAL AND TACTILE SURVEY

Interiors tend to be subjected to minor ad hoc **alterations** more frequently. Particularly for tenanted historic buildings, it is important to keep a log of any changes, and carry out regular visual survey audits to ensure not just the condition, but also the **intactness** of historic interior elements. If the survey is being carried out for the first time after long periods of neglect or misuse, a main purpose is also to uncover any hidden historic elements or finishes obscured by paint, false ceilings, dry walls and so on.

Deterioration symptoms to look out for include cracking, bowing, excessive efflorescence, corrosion stains, out of plane deformation, etc. A simple and quick tactile method to identify a cavity behind an adhered finish is by mechanically tapping on the surface to detect a drummy hollow sound. It is important to map out the pattern and distribution of the historic elements, defects and actual failure mechanism of any debonding. Common defects and their causes include the following:

Debonding refers to the detachment of the tile finish from its bedding adhesive layer, or of the bedding layer or in situ finish from the wall/floor substrate. Detachment could be caused by degradation of the bedding layer or adhesion bond as a result of long-term thermal and moisture differential movement between the various layers, as well as inter-layer shear stresses from ground settlement and heavy human traffic.

Impact damage, such as during construction accidents, may manifest as indentation, surface and edge spalls, and surface fracture or cracks.

Back to previous view

Cracks/Crazing: Where there is no adhesion problem, building movement may result in cracks on the finish layer. Cracks may also occur due to shrinkage of the bedding adhesive, or substrate shrinkage in the case of plaster or screed. This is typically associated with the use of cement-rich bedding or substrate, especially in combination with weaker finishes such as ceramic wall tile and thin cement-based encaustic tiles and terrazzo.

Fine surface cracks, also commonly referred to as crazing, often manifest on glazed wall tiles and in situ cement-based finishes such as terrazzo render. For the former, these are usually confined to the glaze layer, likely caused by shrinkage of the cement bedding adhesive. It can also be due to long-term moisture expansion of the tile clay body, causing stress on the thin and more brittle glaze layer. Surface crazing of a cement-based finish can be due to long-term shrinkage of the material itself, especially for in situ finishes such as terrazzo and screed that experience long-term drying of the surface.

***Left**: Crazing of interior terrazzo render due to long term shrinkage, exacerbated by water seepage causing staining along crack lines. **Middle**: Severe cracks of porcelain dado tiles due to building settlement. **Right**: Crazing on the glaze layer of ceramic tiles.*

Back to previous view

Water ingress due to a a compromised building envelope can lead to **stains and efflorescence** on interior finishes. Infiltration of water from the exterior will dissolve soluble salts within the wall, such as alkali salt from the cement binder or inherent salt in the bricks and mortar, which then travels through existing cracks to emerge on the interior finish, leaving salt deposits along the crack lines. Left untreated, continued salt build-up will lead to permanent staining. Entrapment of soluble and hygroscopic salt within the pores of stones, particularly granite, can lead to stubborn **damp or water marks** due to water retention by the salts. The presence of iron compounds such as iron oxide and pyrite can cause yellowing of stone tiles like granite and white marble.

__Right__: Efflorescence on encaustic floor tiles caused by rising damp.

__Far right__: Long-term water seepage leading to efflorescence, paint peeling, and damage of ornamental plaster render.

Rising damp from the ground can similarly lead to efflorescence, water marks, and yellowing of terrazzo and natural stone. The crystallization of salt can also cause pitting of natural stone such as granite, marble and limestone. The salt could come from the ground, the building, the substrate or even the bedding adhesive. Prolonged seepage through the bedding can cause debonding due to continued leaching of the bedding matrix.

Staining along marble tile joints caused by rising damp.

Back to previous view

Top: Terracotta tiles eroded by heavy use abrasion. *Above*: Mosaic flooring with pigmented glazing worn off, revealing the cream coloured tile body beneath.

Abrasion: Finishes in high-traffic or high contact areas often suffer from abrasion wear – loss of sheen, loss of material, deep scratches and pitting – particularly on softer materials such as marble, terrazzo and cement-based finishes. These can then lead to entrapment of dirt, soot and contaminant due to the increased porosity and surface roughness. Such residues can aggravate the deterioration by retaining moisture. Some contaminants may contain soluble matter and salt, which may then result in crystallization damage, while others may be acidic, causing dissolution of calcite based materials like marble and cement-based finishes. When the pigmented layer is worn off, the tile design may be affected. Some stones can suffer from pitting because of their inherent microstructure and mineral composition, such as the presence of mica and fissures near the surface.

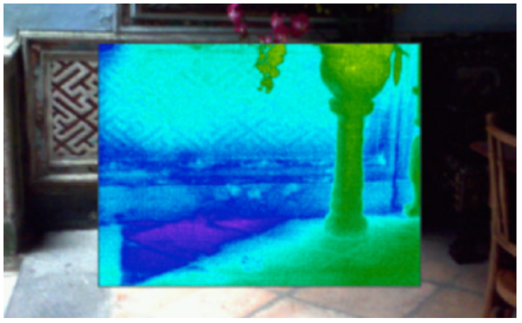
Weathering: In semi-indoor spaces such as verandahs, or areas near courtyards and exterior openings, finishes without added protective finishes may be subjected to different degrees and types of weathering and deterioration, often manifesting as discolouration, shrinkage cracks, pitting, dirt and efflorescence.

Poor maintenance practice and inappropriate modifications: Misuse of high-pressure jets for maintenance cleaning often cause erosion of delicate interior finishes. Ad-hoc patching of cracks, spalling or holes with poorly matched and incompatible material mix can result in ugly patches. It is also a common maintenance malpractice to apply film-forming coating over in situ, precast and tile interior finishes. Apart from damaging the finish layer, water also gets trapped behind the coating, leading to peeling, discolouration and chalking. It is very difficult to remove the coating, especially on textured finish.

Original interior precast and in situ plasterwork revealed after removal of latter-day timber cladding. However, it has been partially hacked for installation of the cladding, causing severe heritage impact.

NON-DESTRUCTIVE TECHNIQUES

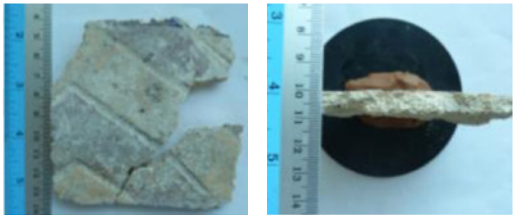
Infrared thermography may be deployed to detect the presence of any cavity behind the finish layer, indicating debonding. The technique can also check for trapped moisture behind the finish layers, which may point to more serious water ingress. However, the use of infrared thermography depends largely on the presence of active heat flow (such as a heated surface giving off heat), which may be more challenging within the more stable thermal environment of building interiors.



Infrared thermography survey of ornamental plaster dado shows cold spots indicating rising damp.

SEMI-DESTRUCTIVE TECHNIQUES, SAMPLING AND LABORATORY ANALYSIS

Sample extraction to determine the **composition** of historic in situ finish such as plaster and terrazzo is further required when conservation repairs and patching need to be carried out, to ensure the design of a materially compatible and visually matching mix. The information includes the type of binder, colour pigments, aggregate types, size distribution and angularity, other fillers and methods of laying and finishing, i.e., polished, acid etched, etc.



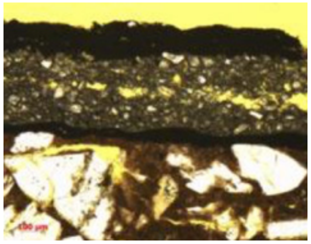
Frontal and section views of ornamental plaster sample extracted for visual, microscopic, and chemical examination.

Back to previous view

The condition or soundness of the surface of the plaster, terrazzo, terracotta, cement tiles, screed and even stone will need to be tested to ascertain if any surface treatment or repair is required. **Localised paint removal** may be necessary.

The investigative tests includes:

- **Petrographic examination** to determine the composition of the materials, including types of minerals, secondary reactions and microstructure such as pore structures, grain sizes, interlayer adhesion, types of stain, presence of past treatment or coating, etc.
- **Surface hardness**, for instance Moh's hardness, scratch hardness.
- **Water (capillary) absorption** for example by the Karsten tube method.
- **Chemical composition analysis** via wet chemical analysis to determine the presence of salt and types of contaminants.
- **Drill resistance measurement** to determine the soundness of stone tiles, terracotta and cement tile.



Microscopic imaging from petrographic examination of historic plaster coating system and composition.

***Left**: Karsten Tube test on encaustic tile to assess water absorption rate by capillary action.*
***Right**: Localized paint removal to verify presence and condition of historic plaster.*

Back to previous view

Conservation, Intervention and Maintenance

Refer to *Chapter 1 'Introduction', 'General Notes on Conservation and Intervention'*, for more information on the key principles and considerations related to conservation and intervention works.

Refer to *Volume 3 Facades, Chapter 2 'Plasterwork', Chapter 5 'Ceramic Tiling' and Chapter 6 'Cladding', sections on 'Stone Cladding'*, for more information on the conservation of plasterwork and stone and clay-based tiles.

Tagging, documentation, and dismantling of historic ornamental cement tiles for off-site restoration. Dismantling of floor tiles should only be carried out if necessary – such as the need for floor slab reconstruction in this case – and it is only feasible if the adhesive bedding is sufficiently weak. Otherwise, conservation works should be carried out in situ where possible.

General cleaning of granite stele by rinsing with water, to be followed by scrubbing to remove loose soot residue.

CLEANING AND COATING REMOVAL

Depending on the types of materials and stains, different methods of cleaning can be applied. It is recommended to always start with the most gentle method, and mock-ups should always be carried out first. The various methods of cleaning include the following.

- **Water processes**: These techniques are used mainly on surfaces where the soiling is water soluble. The methods include water spray, often referred to as 'flooding', nebulous water spray, low to medium water pressure, high water pressure, hot water (typically <95°C) and steam cleaning. Some of the water processes are often used in conjunction with other cleaning methods like poulticing and as pre-wetting or final rinse down associated with chemical cleaning. Care should be taken so as not to cause undesirable effects from the use of water such as corrosion of metal, activation of inherent soluble salt resulting in efflorescence, water penetration and damage to friable surfaces from the use of high water pressure. Where water pressure is used, the nozzle shape and size, working distance and rate of water flow is important to prevent cleaning by cutting. Hot water and steam improve solubility and removal of alkaline cleaners and some solvent-based paint stripers, removal of light greasy soiling and removal of superficial soiling in recess areas.

Back to previous view

***From left**: After rinsing with water, abrasion cleaning is carried out by scrubbing using natural fibre bristle brush to remove loose soot residue. The surface is then sprayed evenly with a chemical stone cleaner and scrubbed in a circular motion, for removal of stubborn stains.*

- **Chemical processes**: It is important that all chemical processes require pH testing of surfaces before treatment, after rinsing, after neutralization and of the water to be used. Various chemicals may be used, including acids such as low concentration, hydrofluoric acid-based and acetic acid, and low concentration alkali-based. Acid-based cleaning solution should not be used on calcite-based finishes such as terrazzo, marble and cement. In the use of these chemicals, pre-wetting and thorough rinsing are essential. Acidic-based cleaning solution may be used to remove efflorescence. If alkaline-based cleaner is used, the surface should be adequately rinsed to remove residual alkaline salt to prevent salt crystallization damage. Biocidal wash can be used to remove biological growth like algae and fungi.

Abrasive cleaning of floor tile using handheld buffing grinder to remove incompatible coating.

- **Abrasive cleaning**: Abrasive cleaning can be carried out with or without water (wet or dry). It is essential to use an abrasive which is softer than the historic finish layer, applied by a skilled hand using the appropriate tool and pressure, to minimize damage. Abrasive cleaning tools range from natural fibre bristle brush, buffing grinder, to rotary jet. The types of abrasive medium include glass beads, sodium bicarbonate, aluminium oxide, silica sand and dry ice. Abrasive cleaning is not suitable for glazed or polished surfaces. During abrasive cleaning, the work surface may be obscured from view by dust, slurry or water mist – depending on the method used. The effectiveness of the procedure depends largely on the skill of the operator who needs to evaluate the effects and make fine adjustments according to the different types of stains and surface conditions.

***Left**: Chemical paint stripper is applied on the in situ ornamental plaster, shrinkwrapped and rested, before removal of paint residue using a scraper. **Middle & right**: Polychromatic ornamental cement tiles were found with extensive staining and glue residue after removal of latter-day vinyl flooring. Conservation cleaning was carried out using pH-neutral soap and cream-based masque, and finished with protective wax.*

- **Poultices, packs and gels**: These are generally used to remove deep-seated soiling and soluble salts. They can be used with plain water, sequestering agents such as EDTA, alkali solutions or solvents for paint removal.
- **Soaps**: Non-ionic soaps diluted in hot and cold water can be used for the removal of greasy and superficial soiling. Ionic soaps are not recommended because of the potential for soluble salt deposition.

Repair of minor cracks on green glazed bottle balustrade using pigmented epoxy.

CRACK REPAIRS

Fine cracks can be sealed with epoxy to prevent ingress of water and soiling. Crazes normally do not need to be treated. Larger cracks will need specific treatment depending on the base materials. For marble and limestone, the cracks may be sealed with epoxy or polyester, often mixed with marble and limestone powders to match the colour. Cement- and lime-based finishes, including terrazzo and encaustic cement tiles can be repaired by patching or injection with fine cement or lime grout. For terrazzo, pigments may be added into the lime or white cement to match the colour. Large cracks in marble, limestone and terracotta can also be repaired with lime with pigments to match. In some cases, nano-lime has been used successfully in the repair of finer cracks. For ceramic tiles, the cracks can be sealed with epoxy.

Back to previous view

Debonding repair by injection.

DEBONDING REPAIRS

Finishes that have debonded but remain in place on walls and floors can be reattached by injection with epoxy or fine lime or cement grout. However, the condition of the substrate and cause of debonding should first be investigated before any attempt to rebond the finish layer. Should the substrate be found to be in poor condition, repairs should be carried out before reinstallation of the finish layer. This may include consolidation, strengthening or replacement of the substrate such as the plaster or screed. In some instances, debonded thick finishes such as stone tiles, encaustic tiles and terracotta may be carefully removed by cutting or wedging for reinstatement. This may be necessary for instance if the floor slab or wall needs to be reconstructed.

Hollow sounding ornamental plasterworks that risk detachment can be stabilized by pinning them back with metal anchors or temporarily held in place with cheesecloth bonded with water-soluble glue. This would then allow the plasterworks to be repaired by injection, pinning or consolidation.

Desalination treatment by poulticing.

SALT TREATMENT

Finishes affected by salt crystallization will first need to be treated by removing the excess surface salt by captive vacuuming. The source of the salt should be ascertained and addressed. Residual salt in the substrate and finish layer can be extracted by desalination with poultices or packs. However, it may not be possible to extract all the salt. Depending on the nature of the salt, chemical stabilization of the salt may be carried out to render the salt insoluble. As these are specialized treatments, advice should be sought from specialists. Salt crystallization can result in disintegration of the surface of the finish layer in the form of a friable and powdery surface and flaking. Drill resistance measurement can be employed to assess the soundness of the salt-attacked surface to determine the degree of deterioration or identify the deteriorated surface layer. Consolidation and strengthening of the surface layer can then be carried out.

Care should be taken in the salt treatment of ornamental plasterworks which may be friable and risk further damage from the treatment. Pre-consolidation may be required before attempting any salt removal, and specialist advice should be sought.

Back to previous view

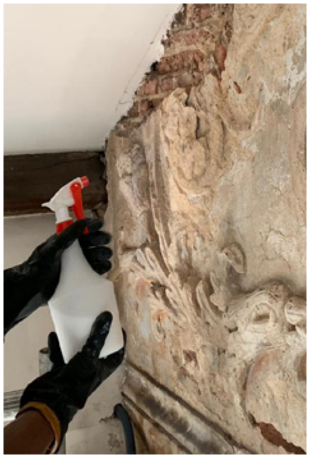
From left: *Damaged in situ terrazzo render; one of the patching trials carried out to ensure visual compatibility of patching mix; selected mix is then used for restoring the rest of the terrazzo finished columns.*

REPAIRS TO EFFLORESCENCE

Surface efflorescence can generally be removed by cleaning with abrasive, dilute acid or sequestering agent. It can be difficult to completely remove cryptoflorescence (subsurface efflorescence) and its presence can result in dark stains due to the hygroscopic nature of the salt trapped within the surface or along the crack lines.

REPAIRS TO CHIPS AND SPALLS

Chips and spalls can be patched with compatible and matching materials. Before patching, the spalled and chipped surface should be adequately cleaned. It is critical to ensure that the patch material is compatible with the finish layer onto which it is to be applied. This includes thermal and moisture expansion and elastic modulus. For marble and limestone, lime mortar mixed to match the colour can be used. The same material may be used for terracotta and terrazzo. For granite and ceramic tiles, epoxy and polyester may be used. Trials will usually be required to match the appearance. Minor spalls and chips may be left alone without the need for any repair. As for ornamented plasterworks, the profile of the ornaments should be recorded and documented before any patch repair can be carried out. String courses can be documented with profile gauges, whilst highly ornamental plasterworks can be recorded via photogrammetry or through 3D scanning. However, the paint layers should be removed to expose the true reliefs of the ornamental plaster before recording them.



After removal of inappropriate paintworks, nano-lime solution followed by silicic acid ester is sprayed onto the highly friable historic plaster for surface consolidation, as part of pre-construction protection works.

CONSOLIDATION

Deteriorated and porous or weakened surfaces – such as due to ageing, salt attack, abrasion and erosion – will normally need to be removed until a sound surface is attained. However, this may result in unnecessary removal of the historic matrix. Consolidant and strengthening of the surface can be carried out.

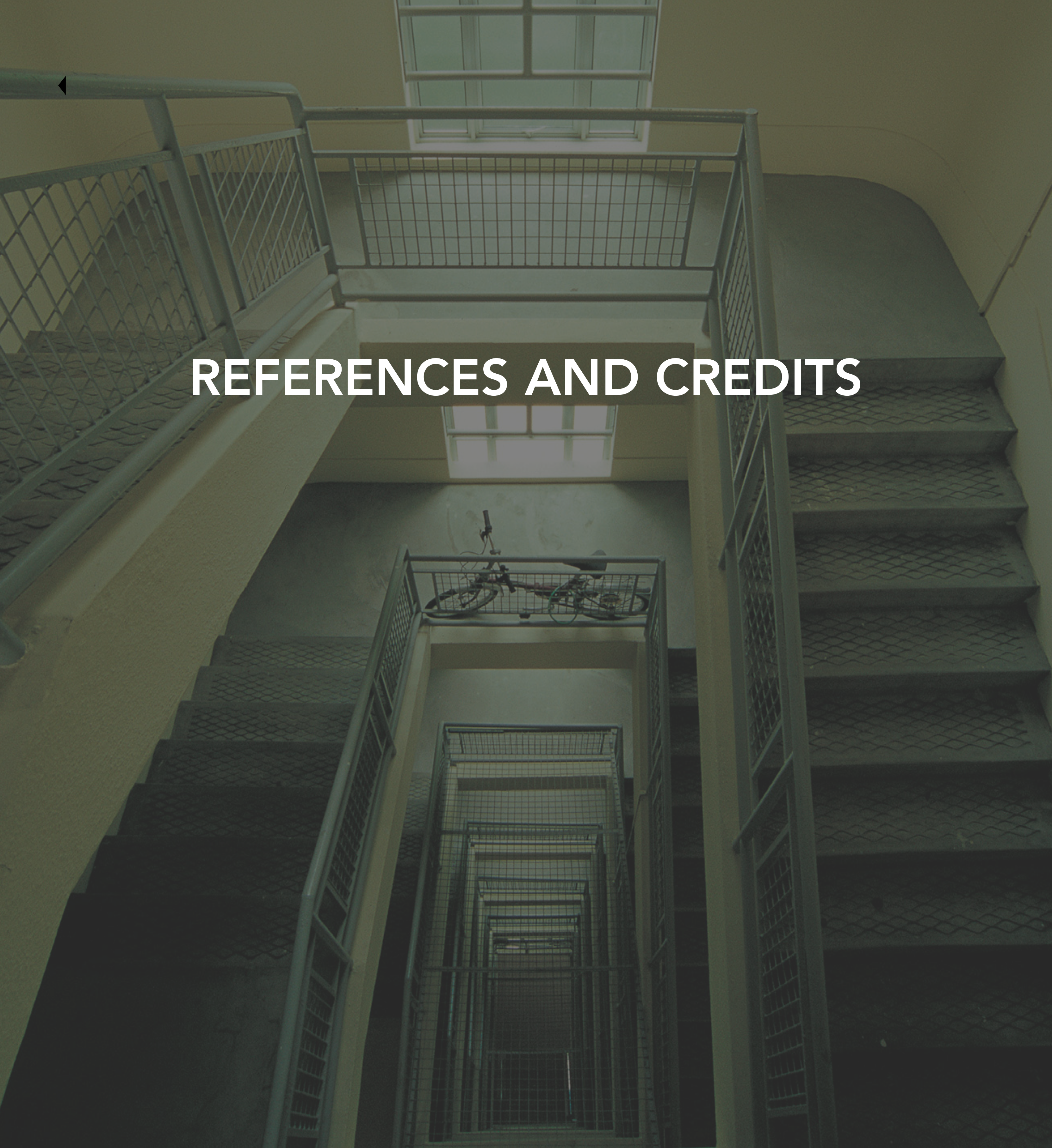
There are a number of chemicals that can be used as consolidant ranging from mineral-based ones like silicic acid ester, lime solution, colloidal silica, alkali silicate and barium sulphate to organic-based like epoxy and acrylic. Typically, mineral-based consolidant is preferred, and the most promising are silicic acid ester and lime solution. Silicic acid ester is best used on siliceous-based materials like granite and terracotta. Lime solution, particularly nano-lime solution, is best used on cement and lime-based materials like marble, limestone and terrazzo. Colloidal silica can also be used on siliceous-based materials like terracotta. Nano-lime solution has been found to be effective as a catalyst for silicic acid ester in consolidating lime-based or calcitic-based materials such as lime plaster. There are different strategies that can be adopted to evaluate the effectiveness of the treatment, which may include drill resistance measurement, tape test and scratch hardness test.

Care should be taken in the application of the consolidant to prevent surface-hardening. Over-application of chemicals can result in whitening of the treated surface or deposition of soluble salt. Trials should always be carried out to assess the application and effectiveness.

WATER REPELLENT TREATMENT

Surface treatment may also be carried out to prevent moisture ingress or water damage. One method is the application of impregnating water repellents such as silane and siloxane. These will render the treated surface hydrophobic, minimizing water absorption. Another approach would be a treatment that would form a layer of film such as acrylic and vinyl coating.

REFERENCES AND CREDITS



References and Further Reading

Beckman, Poul and Bowles, Robert. *Structural Aspects of Building Conservation.* London, etc: Routledge, 2012.

Burkhardt, Berthold, de Jonge, Wessel, Wedebrunn, Ola et. al., *DOCOMOMO Preservation Technology Dossier 2: The Fair Face of Concrete: Conservation and Repair of Exposed Concrete.* Eindhoven: DOCOMOMO International, Eindhoven University of Technology, 1997.

CIRIA. *Structural Renovation of Traditional Buildings.* CIRIA Report R 111. London: CIRIA, 1994.

Clark, Kate. *Informed Conservation: Understanding Historic Buildings and Their Landscapes for Conservation.* English Heritage, 2001.

Croft, Catherine, Macdonald, Susan and Ostergren, Gail, *Concrete: Case Studies in Conservation Practice.* Los Angeles: Getty Conservation Institute, 2019.

Davison, Julian. *Black and White: The Singapore House 1898–1941.* Singapore: Talisman, 2006.

English Heritage. *Practical Building Conservation Series.* London: Ashgate/Routledge, first published 1988, last revised 2012–15.

Feilden, Bernard M. *Conservation of Historic Buildings.* Oxford: Taylor & Francis Ltd., first published 1982, 3rd edition 2003.

Ho Weng Hin, Naidu, Dinesh and Tan Kar Lin. *Our Modern Past: A Visual Survey of Singapore Architecture 1920s–1970s.* Singapore: Singapore Heritage Society, and SIA Press, 2015.

ICOMOS Charter- Principles for the Analysis, Conservation and Structural Restoration of Architectural Heritage- ISCARSAH Principles, 2003.

ICOMOS ISC20C. *Approaches for the Conservation of Twentieth-Century Architectural Heritage, Madrid Document, 2nd Ed.*, 2014.

Insall, Donald. *Living Buildings – Architectural Conservation: Philosophy, Principles and Practice.* Melbourne: The Images Publishing Group, 2008.

Jester, Thomas C. ed. *Twentieth-Century Building Materials: History and Conservation.* New York: McGraw-Hill, 1995

Killmann, Wulf et al. *Restoring & Reconstructing the Malay Timber House.* Kuala Lumpur: Forest Research Institute Malaysia, 1994.

Kong, Lily. *Conserving the Past, Creating the Future: Urban Heritage in Singapore.* Singapore: Urban Redevelopment Authority of Singapore, 2011.

Lee Geok Boi. *Faiths of Our Forefathers: The Religious Monuments of Singapore.* Singapore: Landmark Books, and Preservation of Monuments Board, 2002.

Lee Kip Lin. *The Singapore House, 1819–1942.* Singapore: First published 1988, Marshall Cavendish, 2015.

Back to previous view

Liu, Gretchen. *In Granite and Chunam: The National Monuments of Singapore*. Singapore: Landmark Books, and Preservation of Monuments Board, 1996.

Liu, Gretchen. *Singapore: A Pictorial History 1819–2000.* Singapore: Archipelago Press (an imprint of Editions Didier Millet), in association with the National Heritage Board, 1999.

Prudon, Theodore HM. *Preservation of Modern Architecture.* New Jersey: John Wiley & Sons, 2008

Tan Yeow Wooi. *Penang Shophouses: A Handbook of Features and Materials.* Penang: Tan Yeow Wooi Culture and Heritage Research Studio, 2015.

Urban Redevelopment Authority of Singapore, and Preservation of Monuments Board. *Objectives, Principles and Standards for Preservation and Conservation.* Singapore, 1993.

Urban Redevelopment Authority of Singapore. *Conservation Guidelines Technical Supplement.* Singapore: URA, 1997–98.

Urban Redevelopment Authority of Singapore. *Architectural Heritage Singapore – Architectural Heritage Awards 1994–2004.* Singapore: URA, 2004.

Urban Redevelopment Authority of Singapore. *Architectural Heritage Singapore – Architectural Heritage Awards 2005–2014.* Singapore: URA, 2015.

US Department of the Interior, National Park Service. Series of Preservation Briefs: www.nps.gov/tps/how-to-preserve/briefs.htm (accessed August 2018).

Waite, John G., Gayle, Margot and Look, David W. *Metals in America's Historic Buildings: Uses and Preservation Treatments.* Washington, D.C.: US Department of the Interior, National Park Service, Cultural Resources, Preservation Assistance, 1992.

Selected International Charters
http://www.icomos.org/en/charters-and-texts
ICOMOS 1931 Athens Charter
ICOMOS 1964 Venice Charter
ICOMOS 1994 Nara Document
ICOMOS 1999 Burra Charter
ICOMOS 2005 Hoi An Protocol

Standards and Codes of Practice
BS EN (British Standard European Norm)
ASTM (ASTM International, founded as American Society for Testing and Materials)
SS (Singapore Standards)

Selected Archival Sources

Newspapers:	*Singapore Free Press, Straits Times, Malaya Tribune, Malayan Saturday Post*
Journals:	*Journal of the Institute of Architects of Malaya, The Malayan Architect*
Government records:	Building plans, Annual Reports of Public Works Department/Municipality/ Singapore Improvement Trust

Back to previous view

Acknowledgements

URA and ICOMOS Singapore would like to acknowledge the following parties for their invaluable assistance and generous support:

Datuk Seri Lim Chong Keat
Dr Jon Lim Sun Hock
Estate of the late Jeremy San Tzer Ning
National Archives of Singapore
National Arts Council
National Library Board
Singapore Heritage Society

Image/Illustration Credits

Cathedral of the Good Shepherd
Page 73 (bottom middle).

Estate of the late Jeremy San Tzer Ning (Photographer)
Page 61 (top row middle).
(With courtesy of Singapore Heritage Society) Cover; Pages 13 (bottom row left); 17 (top row right); 28 (chapter divider); 33 (left bottom, right top); 43 (chapter divider); 46 (left bottom); 61 (bottom right cluster of three photos of terrazzo); 64 (all except bottom left); 66 (top); 67 (right); 69 (bottom row left, middle); 71 (bottom right); 75 (left column top and bottom); 91 (chapter divider).

Lim, Chong Keat (Datuk Seri)
Page 64 (bottom left).

Lim, Sun Hock Jon (Dr)
Pages 10 (left); 11.

MAEK Consulting Pte Ltd
Pages 19 (all); 20 (right); 22 (middle); 34 (right); 35 (all); 36 (all); 37; 38 (all); 46 (bottom middle); 47-50 (all); 52-56 (all); 59 (top row left illustration); 79; 80 (bottom left and right); 81 (all); 82 (left margin top, bottom right); 83 (all); 84 (left); 87 (left bottom).

National Arts Council
(Photography by Very! Pte Ltd) Pages 24; 25 (right); 26 (bottom right); 27 (bottom right)
(Photography by Jeremy San) Pages 42 (right); 57 (chapter divider).

Resto-Werkz Pte Ltd
Pages 84 (middle); 86 (left bottom); 88 (all); 90.

Back to previous view

Shanghai Chong Kee Furniture & Construction Pte Ltd
Pages 73 (bottom left); 78 (bottom); 87 (left).

Studio Lapis Conservation Pte Ltd
Pages 12 (bottom row left); 13 (top row); 15 (photo and illustration); 16 (illustration, top row right photo); 17 (top row left, middle); 18 (left, middle); 20 (left); 21 (all); 22 (left, right); 23 (margin, bottom left); 25 (left); 26 (top); 30 (all); 31 (top row all); 32 (all); 33 (right column middle and bottom); 34 (left); 40 (all); 41 (all); 42 (left); 44; 46 (all except bottom row left and middle); 51; 59 (all except illustration); 60 (all); 61 (left column bottom, top row right, second row from top middle and right); 63 (all); 65 (all); 66 (bottom row all); 68 (middle, right); 69 (top left, right column all); 70 (left margin all); 71 (left top); 72 (all); 73 (left top); 74 (all); 75 (right bottom cluster of three photos); 76 (top row right, bottom); 77 (top row first two from left); 78 (left margin top and bottom); 80 (bottom row middle); 82 (left margin bottom); 84 (right); 85 (left bottom); 86 (top row all); 87 (top row middle and right); 89 (all).
(Photography by Randy Loh of Tip Toe Imaging) Pages 23 (bottom right); 58; 85 (top).

Urban Redevelopment Authority
Pages 12 (top row left); 31 (bottom left); 45 (right); 69 (top row middle).
(URA Architectural Heritage Award submissions) Pages 33 (left top); 61 (left top); 68 (left); 73 (bottom right); 75 (right top).

W Architects Pte Ltd
Pages 26 (bottom left); 27 (left column all).

Courtesy of National Archives of Singapore
Pages 14 (right column first two from top); 16 (bottom photo); 17 (bottom left); 29.
Association of British Malaya Collection: Page 17 (bottom right).
Lim Kheng Chye Collection: Page 14 (left column top).
Ministry of Information and The Arts Collection: Pages 10 (right); 12 (top row right); 13 (bottom row right); 14 (right column bottom).
The Japanese Association, Singapore Collection: Pages 9 (chapter divider); 14 (right column third from top).

Courtesy of National Library Board
Lee Kip Lin Collection: Pages 12 (bottom row right); 16 (top row left photo);

Other archival sources
British Malaya: Page 71 (bottom row middle).
Journal of the Institute of Architects of Malaya: Page 77 (top row third from left, bottom).

Web sources (licensed for reuse)
Jack Lee/CC BY-SA 3.0: Page 33 (left middle)
Max Pixel (freegreatpicture.com): Page 39