CONSERVATION TECHNICAL HANDBOOK

A GUIDE FOR BEST PRACTICES

Volume 5 | Doors and Windows

ICOMOS SINGAPORE

URBAN REDEVELOPMENT AUTHORITY

Conservation Technical Handbook
Volume 5 | Doors and Windows

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Cover video still from documentation by Very! Pte Ltd, courtesy of National Arts Council: Bench restoration of timber window by specialist carpenter, Victoria Concert Hall.

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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
President
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 5: Doors and Windows is the fifth book in a series of eight **Conservation Technical Handbooks**. It covers the main types of existing historic doors and windows found in Singapore, and includes closely related elements such as gates, vents, grilles and ironmongery. Key challenges and principles in the conservation and maintenance of these elements, including common local weathering issues and malpractices, are also addressed.

While specialist consultants or builders are required for many of the technical investigations and works mentioned, having a basic understanding and overall idea of what constitutes good conservation/maintenance regime would inform better management and works planning of the historic property.

Chapter 1 Introduction establishes the heritage significance of doors and windows and covers some basic terminology. It addresses common issues encountered in the maintenance and conservation of historic doors and windows, lays out the broad conservation approaches and general guiding principles for best practices.

Chapters 2, 3 and 4 focuses respectively on timber, metal and glazing, the main materials that local historic doors and windows are constructed of. **Chapter 5** looks at an exceptional type of artisan-crafted fenestration that requires particular care – stained glass. **Chapter 6** is on ironmongeries. These chapters are organised such that you can quickly refer to the relevant sections as and when you encounter a particular material. The contents of each chapter are organised under five key headings:

Overview: This section provides a background to the material's history, and explains how or why the material came to be used in particular ways in Singapore's past building practice.

Common Deterioration: Windows and doors are often part of the building exterior and exposed to the weather. They also usually comprise operable parts that are subject to wear and tear. This section explains the common types of defects, issues and their causes, that heritage building owners may face.

Diagnostics: This section provides methods for inspecting and diagnosing issues in doors and windows. Both simple visual and tactile methods of diagnosis as well as specialist investigations are outlined.

Conservation, Intervention and Maintenance: This section outlines common ways of addressing deterioration and their causes, as well as the restoration of dilapidated historic materials and their long-term care and upkeep.

1 INTRODUCTION

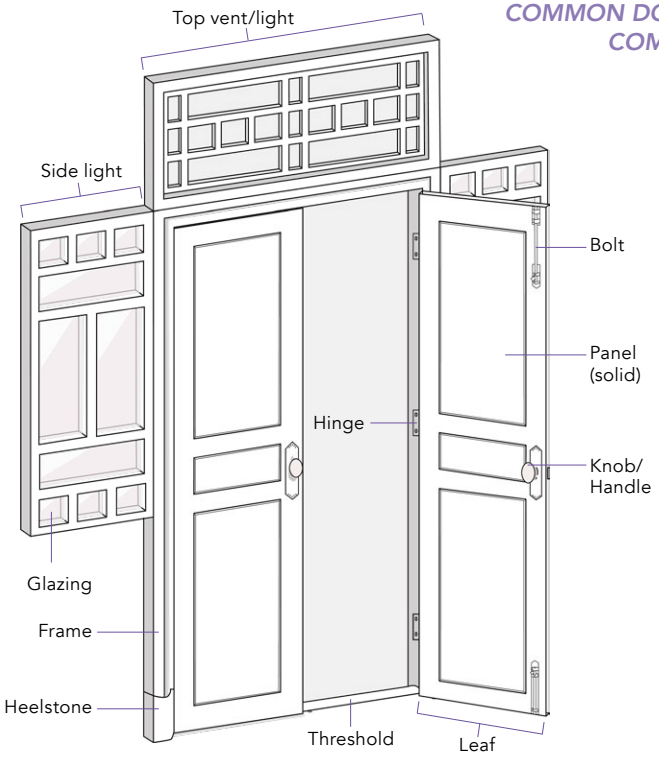
Overview

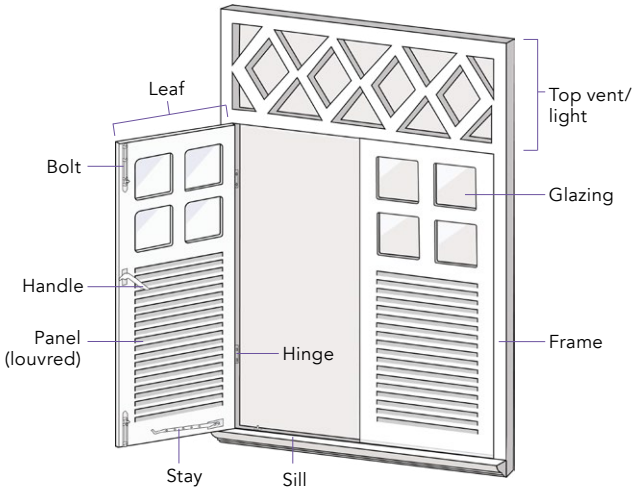
Exterior windows and doors are prominent facade features, providing a sense of scale and, for built-up areas, contributing to the urban streetscape and character. Other than enlivening buildings, they serve to enable access, secure privacy and goods, allow for views out, keep out climatic elements, bring in daylight, filter glare, and so on. Whether exterior or interior, their design, size, material and location on each elevation give an indication of their respective roles (e.g., entrance door, bathroom windows), intended use of the spaces behind, as well as other rich layers of historical information including the local climate (e.g., monsoon windows), building trends of their fabrication period (e.g., imported mild steel windows), and so on.

Fenestration design has evolved through history with progress in material technology and availability, from solid timber leaves and the introduction of glazing that lets light through but keep the rain out, to thin mild steel frames and stronger glass that enable expansive windows. Before the prevalence of airconditioning, fenestration design was also very much shaped by climate, the key local factors being driving rain (awnings and louvres), solar glare (tinted actinic glazing and horizontal fins), and humidity (vents).

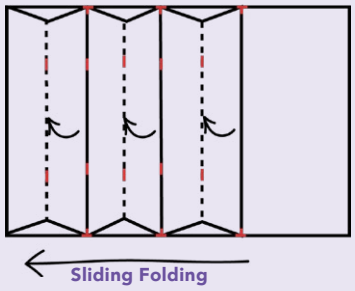
Notwithstanding the vast range of latter-day colour schemes, the character of these shophouses and the Koon Seng Road streetscape is still anchored by the strong datum of the fenestration design.

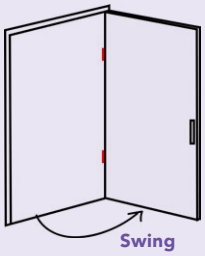
COMMON DOOR AND WINDOW COMPONENTS



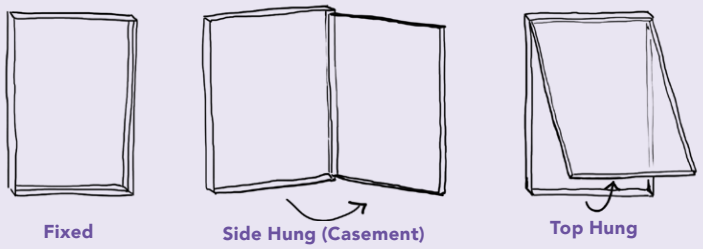


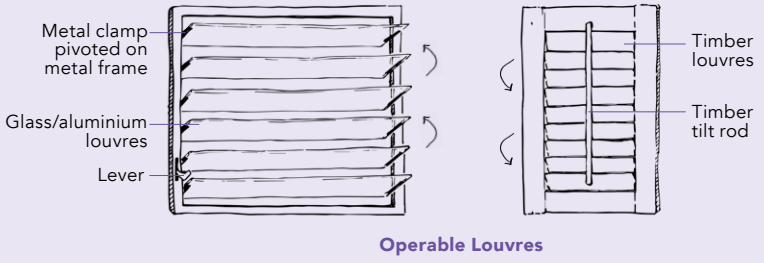
COMMON DOOR OPERATION TYPES

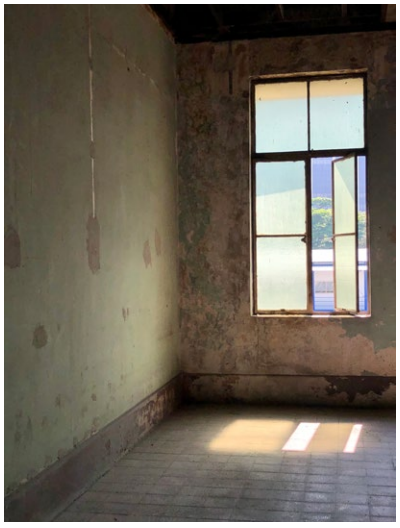




COMMON WINDOW OPERATION TYPES







Top left: *French windows with louvred timber shutters and fanlight, framed by moulded plaster architrave, 28 Sago Street shophouse.* ***Top right:*** *Cast iron feature window with tinted glass, former SSVF Drill Hall.* ***Second row left and middle:*** *Tanjong Pagar Railway Station mild steel pivoted windows with toplight and tinted textured glazing; interior hallway entrance timber door with tinted glazing, top vents and terrazzo heel stone.* ***Second row, right:*** *Folding sliding metal door at ground floor shop unit, Everton Park public housing estate.* ***Left:*** *Top hung high security sliding steel door with weighted lever, former Pasir Panjang Power Station.*

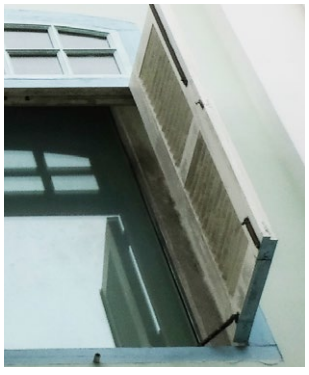
General Notes on Maintenance and Common Issues

Doors and windows are 'workhorse' elements that typically experience a good amount of wear and tear through constant handling, friction, impact, worn hinges, handles and joints, especially of movable parts, exposure to weather for external fenestrations and so on. Regular half-yearly inspection and appropriate maintenance of historic windows and doors go a long way in prolonging their service lives, preventing deterioration, and reducing the need for costly repair or replacement. Particularly for external fenestrations that form part of the building envelope, unchecked deterioration may affect other parts of the building, for example through long-term water seepage into walls.

Most of the time, common door and window deteriorations encountered in local historic buildings arise from a lack of maintenance and inappropriate practices in maintenance or alteration works. Following are key common issues to note in the conservation care of historic doors and windows.

CHANGES IN BUILDING ENVIRONMENT

Increasingly, air-conditioning is being introduced to historic buildings. This should be carefully designed for, with due consideration for overall building environment performance and long-term maintenance. Unfortunately it has become common malpractice to just hermetically seal up fenestration openings using fixed panels. Such inappropriate alterations frequently result in long-term issues of **condensation**, **trapped moisture** and poor interior air circulation, leading to **algae** growth on the exterior and **mould** infestation on the interior.



Far left: *Growth of mould on inner side of window leaf due to lack of maintenance as a result of window opening being sealed off by fixed glass panel.*
Left: *Added secondary windows that are operable allow for maintenance of the historic fenestrations, as seen at this conserved townhouse.*

Advanced wet rot and termite infestation observed in timber window sill as a result of deteriorated weather seal and poor maintenance.

FAILURE OF WEATHER SEALS

Sealant joints and beadings hold glazing in place and keep joints watertight while allowing for thermal movements of frames. Being at the 'frontline' of weather and thermal stresses, they are also often the first elements to wear down, and should undergo timely maintenance and repairs to ensure their durability and performance. Without regular inspections, failure of sealant and beadings often go unnoticed until other elements are affected by water seepage such as rotting of timber frame, paint peeling, or corrosion of metal frame. By then, more intervention works are needed beyond just seal replacement.

Fenestrations located at heights beyond the reach of ladders pose maintenance challenges, such as these mild steel operable clerestories.

NEGLIGENCE AND MAINTENANCE ACCESSIBILITY

Operability of the **movable parts** of historic doors and windows should be checked during half-yearly inspections, especially if they are no longer in frequent use. These movable parts may become misaligned or jammed with long periods of disuse due to accumulated debris, rust, distortion, settlement or even inappropriate paintwork. Joints, hinges, stays, handles, locksets, bolts, operable louvres and tracks should be cleaned of debris, rust or paint, oiled where needed, and carefully tested for degree of operability.

Fenestrations with accessibility issues are often also neglected, and may be tended to only during major renovation works, or when they are badly deteriorated and affecting building operations – such as water infiltration. High-level historic openings beyond the reach of conventional ladders such as clerestories and skylights may be checked yearly with the help of drones, which can also be used for roof inspection.

Accessibility may also be compromised by latter-day renovations, such as boarding up of historic openings or erection of partitions that block them. Fixed glass panels added on the inside of fenestrations, especially high level facade windows, would obstruct even daily cleaning, preventing easy maintenance access from the interior, and should not be allowed. In such cases, accessibility to the affected historic doors and windows should be reinstated by removing the inappropriate works, and any alterations should be sensitively redesigned with due consideration for access, apart from material and design compatibility.

INAPPROPRIATE WORKS

Inappropriate maintenance practices and alteration works such as the following are some of the most common problems affecting historic doors and windows, and even a main cause of deterioration:

- **Incompatible repair and replacement materials** such as less durable timber or mismatched metal type that results in premature deterioration.
- **Inappropriate paintworks** using the wrong paint type, and thick layers of overpainting that obscure original details or materials and lead to trapped moisture, wet rot and corrosion.
- **Poor installation or wrong methods** during repair and maintenance works that cause damage to historic materials, loose joints, compromised weather seals, deterioration of fasteners, distortion, etc. For example, deteriorated lime putty window beadings should be raked out before reapplication, instead of patching or painting over.
- **Insensitive modification** leading to irreversible loss of heritage character and authenticity, such as expedient removal or replacement of historic door and window components and accessories with inadequate consideration for historic materiality and design.
- **Sealing up historic openings** in a way that obstructs maintenance access, traps dirt and causes moisture build-up.

Left: *Insensitive boarding up and replacement of timber french window with 'naco' louvres.* ***Middle:*** *Paint peeling and wet rot due to weathering, lack of maintenance and use of incompatible paint.* ***Right:*** *Historic feature window boarded up on both inside and outside, preventing maintenance, exacerbating deterioration and leading to loss.*

Ad hoc routing of services through historic timber top vent and inappropriate paint work impacting negatively on heritage presentation of shophouse facade.

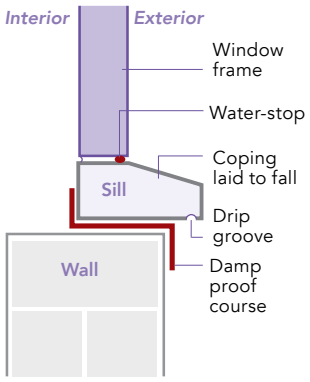
Top: Off-site repair of historic timber window.
***Above:** Addition of a rail with inclined profile at the bottom of a historic timber door/french window helps reduce rainwater ingress by shedding splashback and runoff.*

General Notes on Conservation and Intervention

Historic doors and windows are often subject to modifications over time. They embody a significant part of the building's architectural and heritage value and should not be replaced or modified without due consideration of the resulting heritage impact. Broadly, the need for modification may be due to change of use in the historic property, requirements to comply with present-day building codes and regulations, or enhancements introduced to overcome shortcomings in the original design or craftsmanship. In general, the '3R' principle should be adopted for historic openings to strike a good balance between heritage preservation/ presentation prerogatives and ensuring optimal technical performance.

CONSERVATION REPAIR

High-quality historic craftsmanship and materials are often irreplaceable and should be conserved as far as possible, such as high-quality, skillfully tooled tropical hardwood, or handcrafted textured and tinted glazing that are no longer in production. Rather than heavy modifications or total replacement, historic doors and windows should be retained and assessed for serviceability, and defective items should be given localized conservation repairs and part replacement. Where available, repair works should make use of salvaged historic materials cannibalised from dismantled fenestrations of similar design. Otherwise, new materials should match the properties and details of the historic.

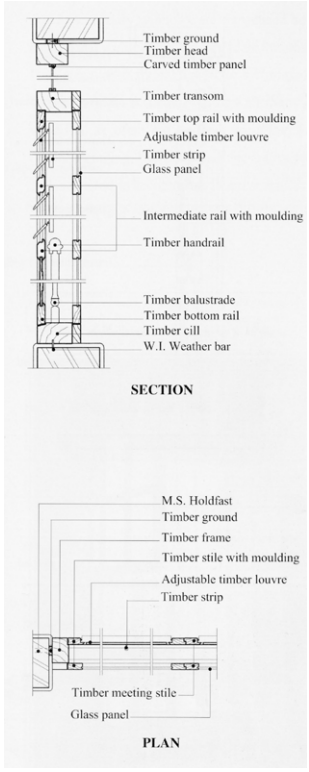


Window Design Enhancement Details

DETAILING ENHANCEMENT

Where the current configuration and detailing are investigated and found to have caused deterioration to the facades, existing historic elements such as awnings, ledges and fenestration should be sensitively enhanced to minimize such maintenance issues. Examples of detailing enhancement include the following:

- 'Water-stop' detail between the historic wall opening and the window/ door frame to prevent rainwater ingress through lime mortar joints.
- Introduction of weather seals between historic frames and leaves.
- Drip detail added onto existing sills and copings.
- Rain-shedding bottom rails introduced onto french windows.



Typical sketch detail of secondary window addition to shophouse french window

ADDITIONS

Additive, reversible interventions can help to strike a good balance between meeting new regulatory or design requirements and preserving the authenticity of the historic building. Some adaptive reuse projects may call for more stringent performance standards, such as hotel requirements for thermal and acoustic insulation. The addition of inner secondary fenestrations fabricated to these specifications would enable the historic outer layer to be conserved in its entirety without modifications.

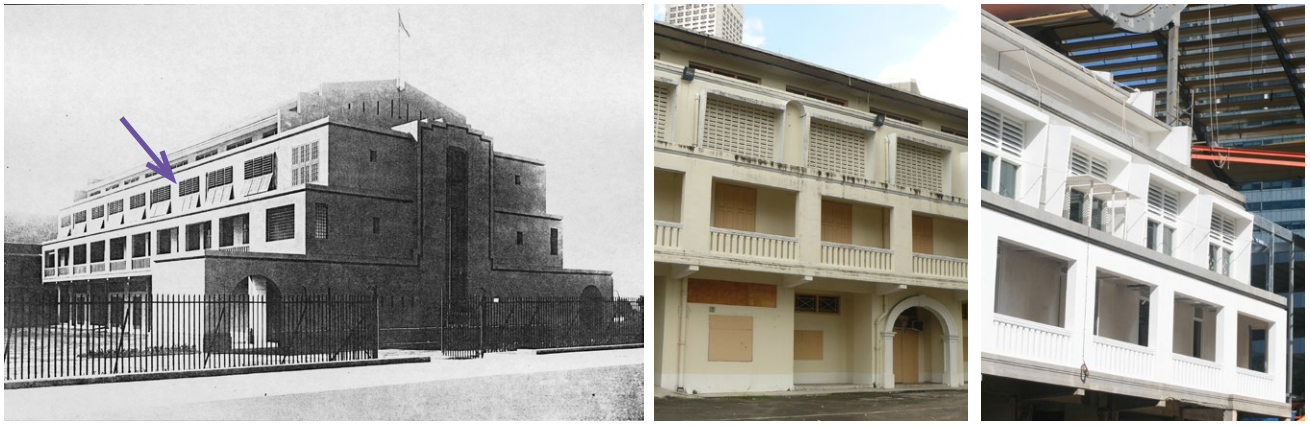
Nevertheless, additions should be designed for minimal visual and physical impact, and not overwhelm the heritage opening. As such, while secondary doors and windows may be in a different material, they should generally assume a simple design that does not obstruct the operation – whether casement, or pivoted, or folding-sliding – nor maintenance of the historic. The design should also take care that installation methods and anchor points do not damage existing heritage elements. Sometimes new framing supported off the existing walls or floor beams may be required if the secondary windows are too large and hefty to be placed within the existing opening.

Another common conservation design compliance is the addition of a safety rail for historic window openings with a sill height that is less than the current safety requirement. These can be sensitively introduced between the historic outer fenestration and the inner secondary fenestration, or incorporated into the design of the secondary window/ door as a sub-frame component, painted in a low-key colour so that it remains 'invisible' from the exterior.

Left: *Interior view of new timber frame secondary windows being installed, sensitively integrated with the historic window design.* ***Middle:*** *Frameless glass secondary sliding doors installed behind historic metal accordion gate.* ***Right:*** *New safety rail (horizontal steel bar) added to historic verandah timber frames of a restored bungalow due to the low sill height.*

REINSTATEMENT AND HERITAGE PRESENTATION

Conservation guidelines and facade control plans may mandate the reinstatement of historic doors and windows that were lost or modified through insensitive alteration works, especially for prominent facade feature openings. Especially for an otherwise intact conserved building, this will restore coherence to its overall heritage presentation. Sometimes, due to the lack of archival records, the historic design of a removed or altered fenestration cannot be verified. Sometimes, when the elevation design has an apparent pattern, it may be possible to draw inferences from other intact historic fenestrations on the building. Otherwise it may not be appropriate to contrive a 'historic' design that was never part of the heritage building. To provide visual coherence while differentiating between the historic and the new, one approach is to create a subdued modern design that references the historic intent – in terms of facade solid-void relationship, overall dimensions, proportioning of subdivisions, materials, etc.



*Original timber louvred clerestories of the former SSVF Drill Hall **(left)** – a key tropical design feature that promoted natural daylighting and ventilation – had been replaced with precast ventilation blocks in the 1960s **(middle)**, when concrete hoods were also added for sunshading and rain shelter. The clerestories have been reinstated to match their original appearance **(right)**, based on careful studies of archival information and surviving samples. The latter-day concrete hoods were retained, together with some detail enhancement to improve the thermal, acoustic and weatherproofing performance of the fenestration.*

SALVAGE FOR CONSERVATION REPAIRS OR UPCYCLING

Where historic fenestration needs to be replaced or disposed for various reasons, it is recommended to salvage these materials to incorporate as part of the new design, or for repair of retained conservation components elsewhere in the building. This can include framing material or even the historic glazing. Reuse and upcycling of salvaged historic material is a good conservation practice that establishes historical continuity, promotes material authenticity, and is also environmentally sustainable. For instance, historic timber windows and doors are fabricated from superior materials (e.g., hardwood timber from mature trees) already well-seasoned in local climate for decades, and workmanship that is difficult to replicate today.

Historic timber components of windows that are not retained are carefully catalogued and dismantled, stored and set aside for reuse and repair of severely deteriorated elements that are conserved.

Historic Crittall brand mild steel framed pivoted windows were carefully dismantled from the former MGS Sophia Blackmore Hall, restored and adapted as a feature screen on the redeveloped site, as part of the heritage interpretion strategy.

Dismantled windows and doors should be reinstalled in the same location for reasons including:

- On-site adjustments when first installed
- Sagging over time
- Composition of door/window types is part of historic design
- Sequence is critical for building function eg. stained glass series depicting biblical narratives

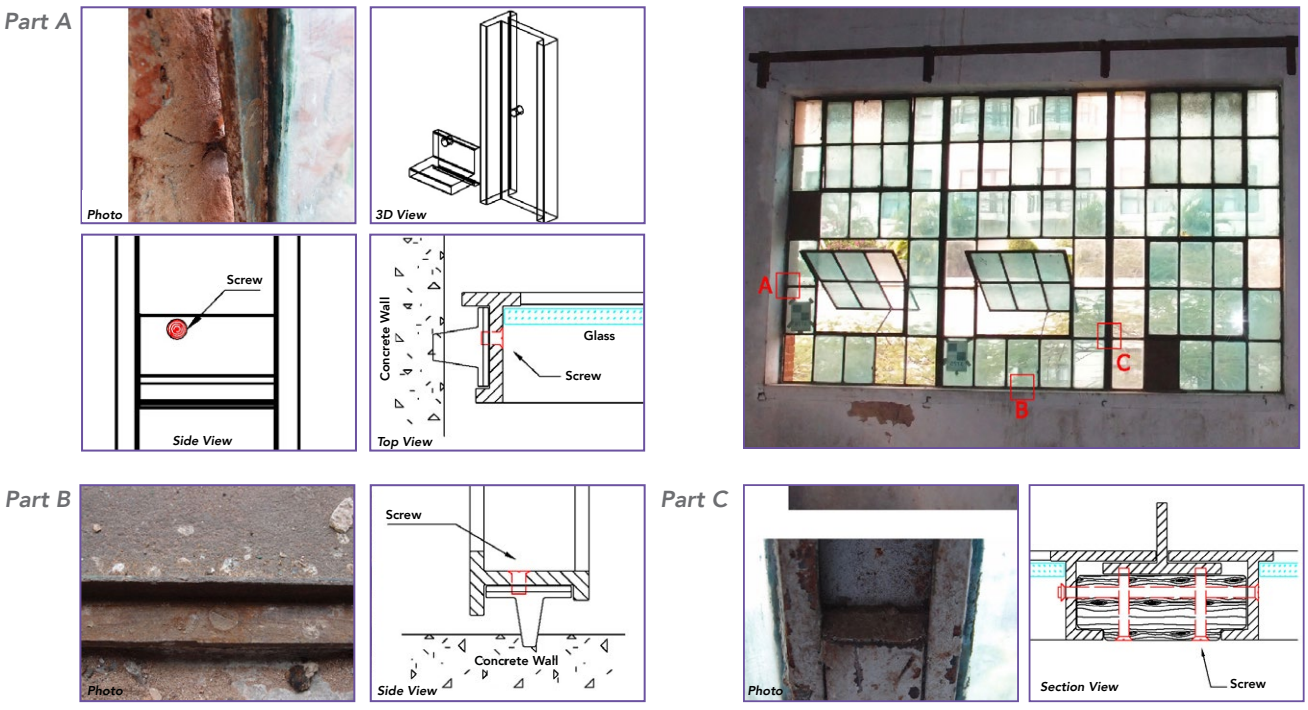
OFF-SITE VERSUS IN-SITU CONSERVATION WORKS

When undertaking comprehensive conservation, the leaves and panels of historic doors, windows, grilles and gates should be dismantled for off-site intervention works under a controlled workshop environment to ensure good quality workmanship and finishing. However, the frames being embedded in walls should be restored in situ, as dismantling will cause damage to both the frame and surrounding walls and finishes.

TAGGING AND DOCUMENTATION

Doors and window leaves to be removed from their frames should be tagged to identify with their existing location to ensure that the panels are reinstalled into the frames from which they were removed. Prior to their dismantling, documentation of the fittings and all the components with sufficient detailed information must be carried out, to ensure accurate reinstatement later on. Similarly, historic ironmongery meant for reuse after reconditioning should be documented, tagged and bagged for storage.

Pre-dismantling documentation of historic mild steel windows includes annotated photographs and connection details.



PROTECTION AND STORAGE

Suitable and adequate packaging and protection should be provided to ensure no damage during handling and transportation of the dismantled doors and windows to the off-site restoration facility that is watertight, dry, adequately ventilated and secured. Suitable and adequate protective measures – such as stacking timber components on pallets and racks to avoid direct ground contact – must be provided to prevent their deterioration, both before and after restoration works are carried out.

SOURCING FOR REPLACEMENT MATERIAL

Replacement components from reputable and certified sources should match the original in terms of physical and chemical properties to ensure optimal visual and material compatibility, in order to minimize maintenance problems later on. For example, replacement timber elements 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.

ENGAGING SPECIALIST TRADES FOR RESTORATION/REPLICATION

It is highly recommended that only experienced tradesmen and artisans be engaged for the restoration and replication of historic timber and metal fenestration, glazing and ironmongery.

Careful tagging, dismantling, protection and storage of historic timber windows. The frames may be considered for dismantling if it does not affect adjacent sensitive historic finishes such as ornamental plaster, and temporary bracing support for the opening must be installed immediately after frame removal.

2 TIMBER

Overview

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

Doors, windows and vents found on vernacular Malay houses, early shophouses/townhouses, and other prewar colonial-era buildings were predominantly of timber construction. These typically comprised a framework of rails, stiles and mullions connected by mortise-and-tenon joints, infilled with solid panels, grilles, latticework and/or louvres (fixed and operable). Early windows were mostly shutters that could be closed when it rained or privacy was called for, often with louvres letting in filtered daylight and airflow. Glazing was a premium imported item that in the early days could only be found on buildings of prestige or owned by the wealthy. It was also common to install low timber gates at the top of interior staircases in historic bungalows, likely for safety and privacy of the upper floor, which was usually intended for bedrooms.

Fraser and Cumming

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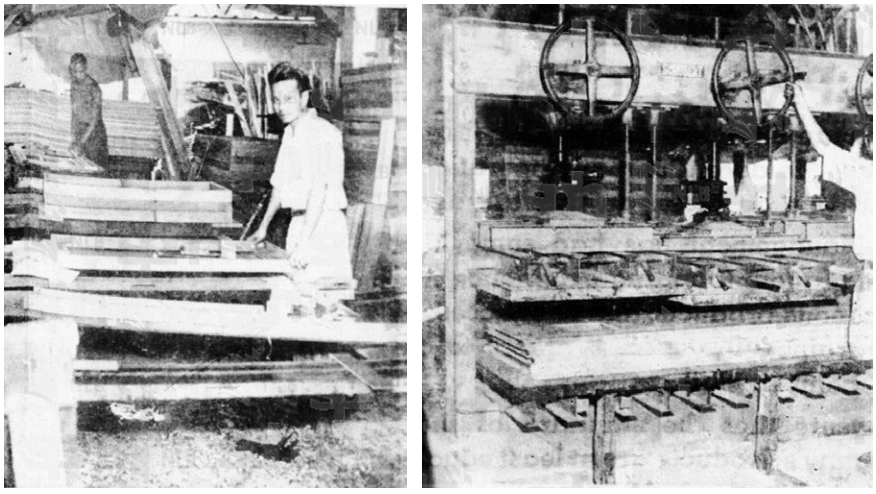
1902 advertisement of a timber merchant who supplied doors and windows.



Local timber workshop in the 1950s producing doors, windows and built-in furniture from local hardwood, teak and plywood.

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

While some timber doors and windows were imported – especially for designs requiring special woodwork equipment – many were produced by local carpentry workshops using tropical hardwood from Malaya and the region such as kapur, chengal and teak. Historic doors and windows were also usually **painted** or **coated** to provide a protective layer and for aesthetic reasons.

*Early shopfront fenestration types with dismantleable timber boards **(top)**, and split top and bottom panels or 'Dutch' windows **(above)**.*

Early shophouse fenestration types, designed to facilitate mercantile and/or warehousing activities of the period, reflect Singapore's history as a colonial trading outpost. An example commonly found in the Kreta Ayer (Chinatown) area comprises a timber frame shopfront with a central double swing door flanked by **full-height dismantleable timber boards** that provided security, but that could also be fully removed to create a wide opening when the shop/warehouse is open for business/loading. Another example is the **'Dutch' door/shutter**, similar to those found on Dutch colonial-era buildings in Malacca, and can still be seen at Bussorah Street. Typically, an opening has top and bottom operable solid timber panels. The top could be opened for ventilation while the bottom remains closed for partial screening, or both could be opened for loading and trading. When opened, the bottom panel of a 'Dutch' window can also be propped up as an extended display surface for goods.

The **arrangement of historic fenestrations**, especially the highly visible feature doors and windows, would usually be designed as part of the interior or exterior elevation composition, whether in symmetry (e.g., door flanked by two windows in townhouses) or rhythmic datum (through varying door/window types, e.g., in school buildings). In response to the **local warm and humid climate**, historic fenestrations were usually conceived as part of the building envelope and passive ventilation system. Timber doors and windows often came with louvred or latticed panelling, a typical feature being **operable timber louvres**, or accompanied by top or bottom **vents**. Some historic residences feature extensive timber vents, along verandah parapets, the top of walls and partitions, to facilitate cross-ventilation across the house. Some common historic timber door and window constructions include the following:

Board and batten door

Framed and Panelled: A door/window with a frame consisting of stiles (vertical members) and rails (horizontal members) with panel inserts. Timber louvres or glass panes could take the place of timber panel inserts. This is the most common type of door/window construction.

Plank/Board and Batten: A simple door/window constructed of timber boards in a row, parallel throughout its length and held together by perpendicular and diagonal support battens. There are also variations of such construction, for example, double planked as well as battened and ledged. These are often deployed as service area doors for heavy usage.

Flush: This is a modern construction method with the invention of veneers and is found predominantly in postwar door construction. The door frame is concealed behind veneers, with plain facing on both sides.

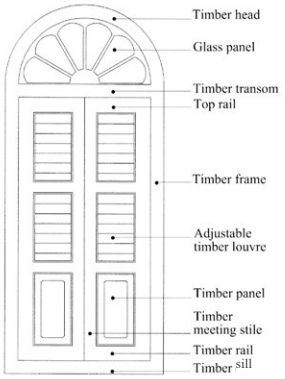
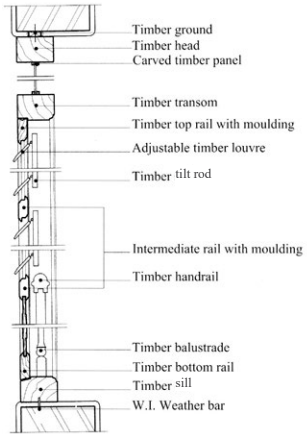
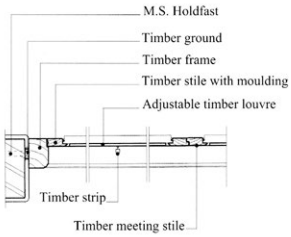
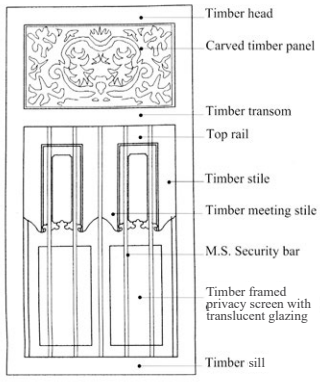
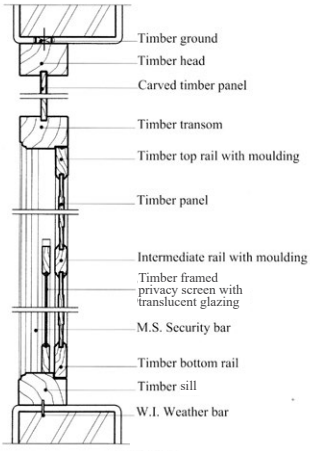
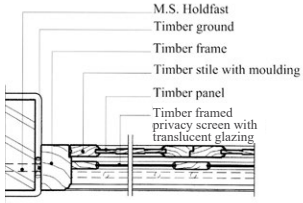
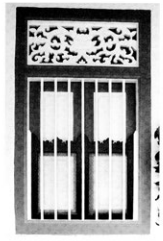
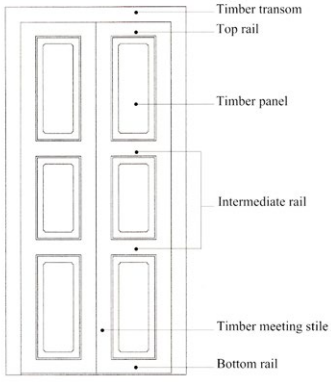
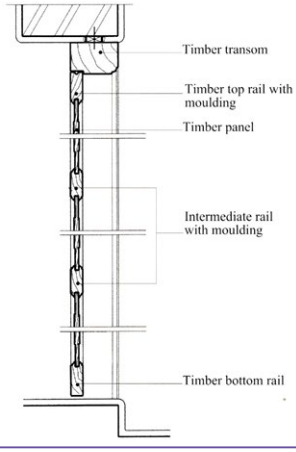
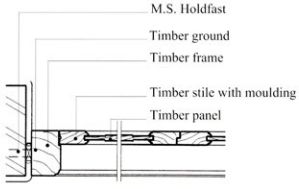
Left: *French panelled window flanked by ox-eye windows, Syed Alwi Road shophouse.* ***Right:*** *Carved timber louvred shutters with a central french window, in composition with plaster and ceramic shardwork ornamentation, townhouse at 157 Neil Road.*

French windows with louvred and carved timber panels, and lattice toplights/vents.

Left, middle: *Elaborate carved timber panel windows.* ***Right:*** *Operable timber louvres, controlled by a tilt rod, faciliates natural ventilation.*

From left: *Casement window with glazed lattice; Low timber safety gate at the head of the staircase; Lattice doors and top vents forms breatheable building envelope.*

TYPICAL SHOPHOUSE/TOWNHOUSE FACADE TIMBER DOOR AND WINDOW DETAILS

Elevation	Section	Plan	Photo
			
			French Window
			
			Ground Floor Window (along five-foot way)
			
			Main Entrance Door

PINTU PAGAR

'Pintu pagar' or fence door is a shorter spring-hinged double swing door that is usually paired with a regular double door on the inside, to provide some measure of privacy screening when the main doors are open for ventilation. The use of such doors suit very well the tropical climate of Singapore. Pintu pagars were commonly used at the ground floor facade of shophouses and townhouses, and also found in colonial-era bungalows where they acted as privacy screens to the bedrooms while allowing cross-ventilation.

These fence doors were a common feature through the pre-war years, evolving a wide variety of styles and finishes. Most existing examples come with minimal ornamentation with carved motifs on only one side. A select few exhibit intricate ornamentation, latticework carvings and the use of gilded finish. In fact, a pintu pagar at the main entrance would have been one of the first elements seen by a visitor, and a highly visible symbol denoting the status of the household.

Pintu pagars are made of timber, usually tropical hardwood. The leaves are hung via brass or bronze spring hinges from timber posts, usually also ornamented and fixed to the main door frame. The leaves are typically panelled, infilled with solid or latticework carved timber, or tinted and textured glazing. Apart from the hinges, other ironmongery features include latches and stays to keep the leaves in position.

Exterior- and interior-facing sides of a pintu pagar with coloured embossed glazing panel.

Pintu pagar with intricate carvings and gilded wood at the entrance of a townhouse at 157 Neil Road.

Above left: ***Detail of a spring hinge.*** *Above right:* ***Pintu pagar in a house interior setting.*** *Left:* ***Pintu pagar with Chinese motifs and latticework panelling at an Emerald Hill townhouse.***

Common Deterioration, Causes and Diagnostics

Refer to *Chapter 1, General Notes on Maintenance and Common Issues* for important concepts and issues to be aware of when taking care of historic doors and windows, and to take into account when planning for conservation maintenance and intervention works.

Timber is an organic material. It is prone to both biological decay, such as that caused by bacteria, fungi and insects, as well as non-biological decay caused by weathering, moisture and contaminants. However, timber fenestrations can be durable if they are properly designed, constructed and maintained.

VISUAL AND TACTILE SURVEY

Apart from pre-condition surveys carried out prior to conservation works, it is generally a good practice to carry out regular basic visual and tactile maintenance surveys of timber openings. Common signs of deterioration to look out for include the following:

- **Wet rot** caused by fungi that attack timbers by disintegrating the cellulose and lignin of wood. Affected areas are usually where water is easily trapped and retained within the wood, such as the ends of wood embedded in or abutting masonry substrates, for example at window/door frames. It is also frequently found on the bottom rails of door or window leaves, which are in close proximity to the ground/floor, and sill. Such water retention issues should be checked for and addressed early on to prevent the onset of wet rot and termite attack.

Refer to *Volume 4 Structure, Chapter 3 Timber* for more information on deterioration and different diagnostic methods for timber.

Wet rot at susceptible locations – door kickboard and window sill.

Termite attack in timber components leaving extensive trails.

- **Termite attacks** in local historic buildings are typically caused by dry wood termites and/or subterranean termites. Subterranean termites nest in the ground, while dry wood termites nest inside the wood they are infesting. Subterranean termites build mud tubes tunnelling through the ground to reach the target building while protecting them from predators and dehydration. Dry wood termites are winged and infest the target building by air, requiring less moisture to survive, with no contact with soil. Termites tend to infest wood that is already softened from constant exposure to damp conditions, for instance where there is water seepage or pooling.
- **Deformation or dislodgement** of openings may be caused by building structural movements or thermal movements of the timber components. Some building settlement may be historic and long since stabilized; should the doors and windows be operational and in serviceable condition, there is no need for intervention. Timber beadings and frame joints found cracked or loosened should, however, be rectified (by skilled carpenters).
- **Wear and weathering** is commonly observed on external timber surfaces, such as facade doors and windows, and includes wearing down or peeling of protective paintwork and beadings, and degraded timber surface. When defective paintwork is left to deteriorate, the exposed timber surface will be subjected to repeated daily cycles of ultraviolet light exposure, wetting and drying. Although a slow process, if left unchecked this will eventually lead to surface roughening, checking, splitting, cracking and erosion of wood cells.

Far left: *Dislodged louvres, wet rot and rusted ironmongery.*
Left: *Detail of weathered timber window.*

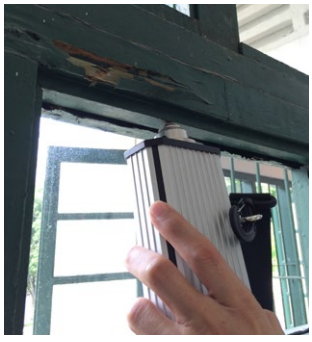
Most local historic timber fenestrations would have been originally finished with some form of preservative or protective coating, and even painted artwork, such as door god murals at the main entrance of Chinese temples. In such cases, **pigment composition analysis** and other investigation of the coatings, and detailed documentation if needed, should be carried out prior to any interventions.

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

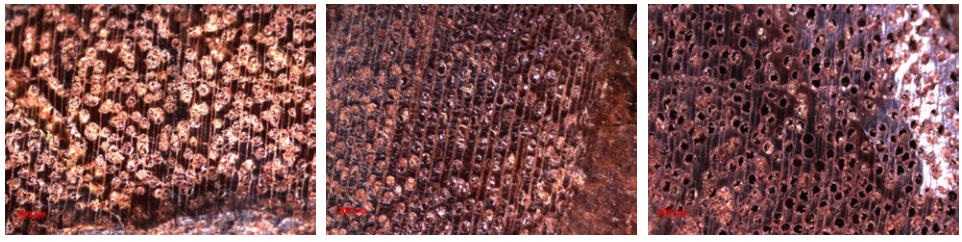
NON-DESTRUCTIVE AND SEMI-DESTRUCTIVE TECHNIQUES

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:

- **Moisture check** by the common 2-pin method to assess the degree of moisture retention in deteriorated components to determine the cause, condition and integrity of the timber member.
- **Timber resistograph** 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 members.
- **Prick test** is also a semi-destructive method to check the soundness of timber surface. The tester inserts a sharp tool (e.g., 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. This test should be carried out at a less visible location on the fenestration.
- **Species identification** calls for sampling extraction by removing a small piece of wood (from a less visible spot) 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.



Timber resistograph carried out on window frame.



Left to right: *Microscopic view of balau, chengal and kapur wood species.*

Conservation, Intervention and Maintenance

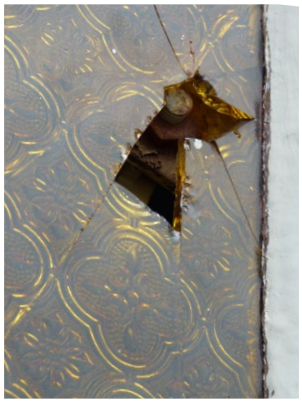
Refer to *Chapter 1, General Notes on Conservation and Intervention* for important concepts and issues to be aware of at the outset of planning for conservation works, including documentation, protection and dismantling precautions.

Refer also 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; a similar concept can be applied even for non-structural timber such as doors and windows.

MINOR/MAINTENANCE INTERVENTIONS

Even for intact doors and windows, minor repairs and conservation works may be called for to address general wear and tear and issues arising from lack of maintenance, or to undo past inappropriate works:

- Cleaning only if necessary with gentle pH-neutral cleaner, avoiding harsh detergents and too much liquid.
- Lubrication of hinges and ironmongery, dusting/oiling of timber components.
- Rectifying jammed or dislodged components.
- Removal of debris build-up that interferes with window and door operation.
- Redecoration of plain painted surfaces using appropriate timber paint (once every 5–10 years).
- Removal of inappropriate paintwork and paint build-up that traps moisture, obscures historic details and obstructs operation, by careful scraping, gentle sanding and – only if necessary – appropriate chemical paint stripper.
- Replacement of broken glass, damaged beadings and/or putties using appropriate materials matching the historic.
- Disinfestation of pests, bacteria and fungi.



Regular maintenance repair includes the temporary sealing up and eventual replacement of any broken glazing, to keep out any water ingress that may cause further damage to the historic window and even the building interiors.

Timber doors and windows dismantled for off-site storage and bench restoration in a carpentry workshop. Components such as louvres and frames can be taken apart for closer study of joinery details and thorough cleaning/paint removal.

FURTHER INTERVENTIONS

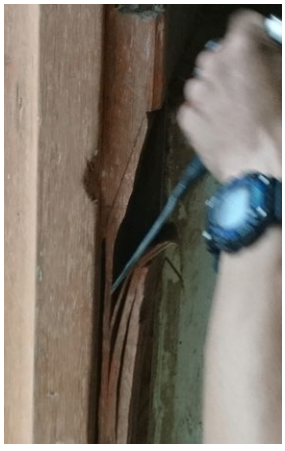
Where the damage of timber components is found to be severe or complex, localized replacement or reinforcement can be carried out; total replacement, which would result in irreversible loss of historic material, should be avoided.

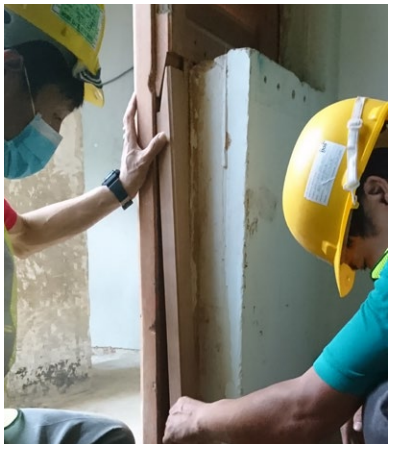
For major restoration works, elements that can be readily dismantled such as door and window leaves may undergo **off-site restoration** in a sheltered workshop, with better manoeuvrability. However embedded elements and main frames should be restored **in situ**, as dismantling may cause damage to the timber components as well as surrounding wall and finishes. Below are some options to be considered for rectification and restoration work; the actual mix applied and method used should be carefully designed and tested to suit each situation:

- **Surface patching** using epoxy resin-sawdust mix to address minor surface damage, such as fine or shallow cracks.
- **Chemical impregnation** by injection of epoxy resin-sawdust filler mix into cavities detected in the target timber member. This is intended to consolidate localized weak points and return the integrity to the wood without sacrificing the historic material.
- **Timber-to-timber repair**, which is localized surface patching or whole-section replacement by scarfing, may be required for the affected timber frames and panels if the defect appears to be substantive and beyond repair. 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.

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. Traditional natural material systems include linseed oil. Transparent or translucent varnishes can be used if the timber grain is supposed to be revealed, such as teak elements. 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.





Left to right: *In-situ timber-to-timber conservation repair – decayed wood is removed and scarf joint carved from the existing. Replacement member of the same species is tooled and coated with preservative before being fitted to the existing frame.*

3

METAL

Overview

Refer to *Volume 4 Structure, Chapter 4 Metal Structures, Overview*, section for related information onthe history and manufacturing processes of cast iron, wrought iron and steel.

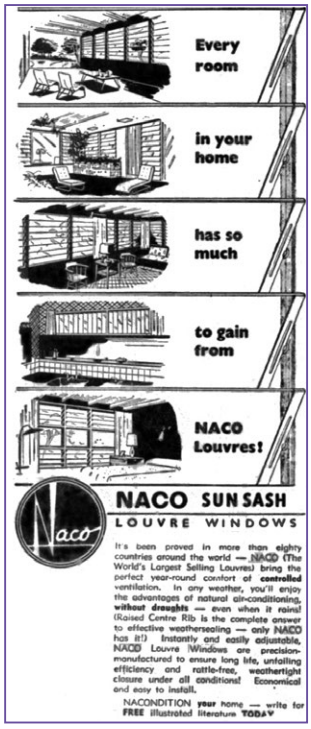
The application of iron for non-structural building purposes, such as in doors, windows, gates, fencing and grilles, was likely introduced to Singapore by colonial traders. Particularly in the late 19th century, with increasing trade and prosperity, the use of decorative **wrought iron** and **cast iron** products imported from Britain, such as gates and grilles, became a staple feature on houses and buildings as both a display of wealth and a security feature for the property.

Metal doors, windows, gates and grilles were imported in the early days, such as Walter MacFarlane cast iron products, Crittall mild steel windows and Bostwick steel collapsible security gates from Britain. By the 1930s, however, locally produced counterparts were available in the market supplied by European-founded metal factories.

Right: *1935 advertisement for locally manufactured metal windows, collapsible gates, and more.* ***Far right top:*** *Decorative wrought iron window security grille at the Tower House (1890s) with Art Nouveau design.* ***Far right bottom:*** *Naco type aluminium and glass louvred windows were a common feature of HDB flats (c.1965).*

Refer also to *Chapter 6, Ironmongery*, in this volume for the historical overview, issues, diagnostics and conservation intervention of door and window accessories such as hinges, handles, locksets, stays, bolts, levers and so on.

The predominant material used was **ferrous metals**, and known surviving heritage metal doors and windows are mainly of wrought iron, cast iron or mild steel. The more costly bronze and brass were mainly reserved for **ironmongery** such as hinges and handles. A characteristic Art Deco feature, bronze doors were used at high profile buildings such as the bronze collapsible gates at the former Kallang Airport (1937), and "extruded manganese bronze" triple-opening doors at the MacDonald House (1949) banking hall, but many have long since been replaced. A rare surviving example can be found at the former City Hall (current National Gallery). Elaborate historic cast iron windows could be found adorning grand former government buildings such as on the main facades of the Straits Settlement Volunteer Force Drill Hall (1931) and former Tanjong Pagar Railway Station (1932).

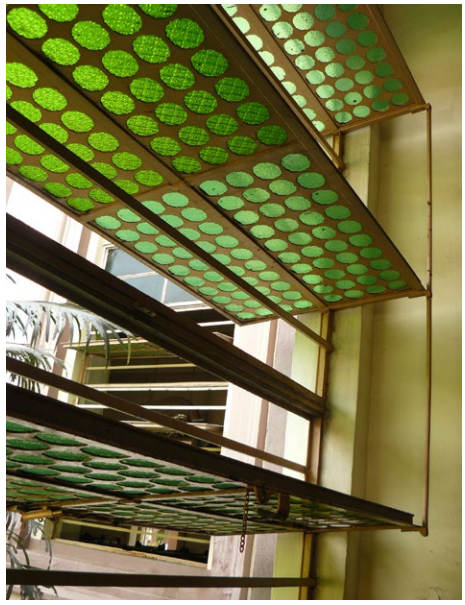


1958 advertisement for 'Naco' windows as an economical option for 'controlled ventilation', with the marketing line 'Nacondition your home'.

Technological advancements in steel and sheet glass production enabled the creation of **mild steel** windows with thin frames and large glass expanses, befitting reinforced concrete buildings that could achieve bigger openings. These were introduced to Singapore as early as the 1910s, touted as being more lasting than timber windows while allowing more daylight through. Like cast iron windows, these were prefabricated patented products and came with accessories such as hinges, handles and stays. Recommended in prewar advertisements for 'offices and bungalows', early examples included premier commercial buildings at Raffles Place, Capitol Theatre (1931), Chee Guan Chiang House (1938), and government buildings, including schools.

After World War II, global industrialisation resulted in cheaper and more widespread use of metal products. At the shopfront, mild steel sliding folding panels and roller shutters increasingly replaced timber panels. **Aluminium** became affordable and gained popularity for being rust-resistant, while refinement of extrusion technologies enabled large-scale commercial production of standard doors and windows in the 1960s-70s. The British brand of aluminium 'Naco' window with adjustable glass or metal louvres made inroads into the local market for being well suited to the tropical climate. The metal factory Lea Hin Co. supplied locally manufactured mild steel casement windows and metal louvred windows to public housing and government building projects in the 1960s and 1970s.

Left: *Mild steel fixed and top hung windows with integrated safety railing illuminating the staircase landing at Sophia Blackmore Hall, former Methodist Girls' School, Mt. Sophia campus.* ***Right:*** *Mild steel pivoted window with security lattice grille installed in 1939 at the Cathedral of the Good Shepherd.*



Left top: *Brass doors at City Hall (1929).* ***Left bottom:*** *Cast iron window straddling two storeys at Tanjong Pagar Railway Station (1932).* ***Below from left:*** *Bronze windows supplied by Henry Hope and Sons Co., and 'Dreadnought' steel fireproof door with counterweight door closer at Pasir Panjang Power Station (1953).*

GATES, FENCES AND GRILLES

Grilles and gates are security features fitted at entryways and fenestrations of buildings. Historically, metals such as wrought iron, cast iron, mild steel and bronze are construction materials favoured for their strength, lightness and workability. Gates and fences function to secure compounds whilst allowing some visual permeability. Grilles at windows and doors allow these to remain open for light and ventilation, while keeping out unwelcome visitors – such as at the ground floor openings of shophouses and townhouses with constant exposure to passers-by. Also commonly found on historic military facilities, these often took the form of simple rods and flat bars.

1930 advertisement for imported Bostwick collapsible gates, mainly used for shopfronts and public buildings.

More elaborate and ornate gates and fencing could be seen at well-appointed European-style buildings, and also buildings of religious and charitable organizations supported by wealthy families. Examples include Chinese temples such as Thian Hock Keng's iron fence, the former Tao Nan School (now Peranakan Museum) and the Convent of the Holy Infant Jesus (now CHIJMES). The surfaces of such cast iron products are sometimes painted in different colours or even gold-gilded.

Collapsible or expanding steel gates, also widely known as 'Bostwick gates' after the original UK patentees Bostwick Gate Shutter and Co. Ltd., could be found here as early as the 1900s, especially at commercial, government, and other premises where security was a key concern. Two sets of collapsible gates may be found still in their original locations in the former Tanjong Pagar Railway Station (1932) between the main hall and the platforms.

FENCES

From left: ***Ornamental cast iron fencing and gates at Thian Hock Keng (from Scottish foundry Walter MacFarlance & Co.), Old Parliament House, and featuring Art Deco design at the Tanjong Pagar Railway Station.***

These ornate imported metal elements contributed to the rich and eclectic building styles that characterized bustling trading posts and colonial cities of the era where migrant communities of varied cultures freely borrowed, adapted and exchanged goods, culture and trends.

The postwar years saw mild steel grille gain popularity – given its malleability, thin flat bars between 2.5 and 4mm thick could be worked by local artisans without special equipment to a wide variety of grille designs, and were more affordable than cast or wrought iron ones. The flat bars were bent and shaped using preformed moulds, and joints between members were skillfully welded creating a seamless design. In the 1970s and 1980s, expressive custom mild steel designs were gradually replaced by standard prefabricated aluminium lattice grilles.

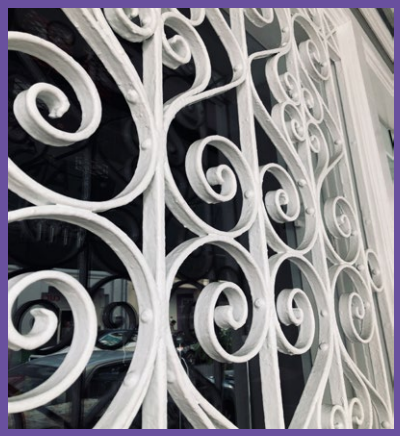
GATES

From far left: ***Convent of the Holy Infant Jesus (1900s), Tao Nan School (1912, now Peranakan Museum), Straits Settlement Volunteer Force HQ (1931, now part of South Beach)***

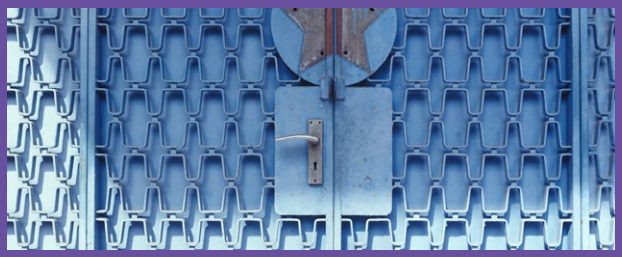
COLLAPSIBLE/SLIDING FOLDING GATES

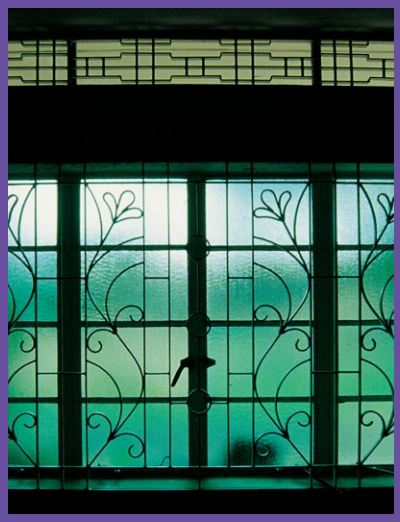
From far left: ***Collapsible gates at Tanjong Pagar Railway Station (1932); Mild steel sliding folding doors with integrated ventilation grilles (sealed up) at Everton Park Housing Board estate ground floor shop units (1965).***

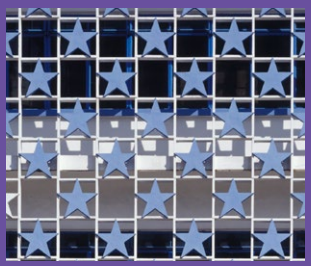
GRILLES AND VENTS



PREWAR DESIGNS – above from left: ***Simple mild steel vertical rods at Neil Road shophouse; Riveted mild steel strips formed into ornamental tendrils at Keong Saik Road shophouse; Grille integrated with cross and initials at St. Jospeh's Church Parochial House;*** *Left:* ***Decorative cast bronze top vent with plant and floral motifs above a house interior door.***







POSTWAR DESIGNS – top from left: ***Geometric mild steel grille gates at Khong Guan Biscuit Factory; Auspicious bat and coin motif at the former Chui Huay Lim Club; Floral motif set against translucent glazed windows, contrasted by geometric top vents.*** *Bottom from left:* ***Inhouse made sunshading mild steel grille bearing the company's star logo at Lea Hin Co.; Bronze-plated mild steel grille with cloud motif at Brittania Club (later NCO Club, 1952); Grille with lantern motif complements circular openings at Cundhi Gong Temple.***

Common Deterioration, Causes and Diagnostics

Refer to *Chapter 1, General Notes on Maintenance and Common Issues*, in this volume for important concepts and issues to be aware of when taking care of historic doors and windows, and to take into account when planning for conservation maintenance and intervention works.

Refer to *Chapter 6 Ironmongery*, in this volume for the issues and diagnostics of door and window accessories such as hinges, handles, locksets, stays, bolts, levers and so on.

VISUAL SURVEY

Corrosion is the most common form of defect found on metals. It is particularly damaging for ferrous metals, which undergo oxidation in the presence of air and water to form a layer of reddish iron oxide on the surface. The rust layer is uneven, patchy, friable and also permeable, so the metal underneath will continue to undergo oxidation with exposure to moisture and air. In severe cases, such as on a thin decorative panel, the rust can bore a hole through the metal and compromise the element's structural integrity.

Deterioration of metal doors, windows, grilles and gates is often caused by **inappropriate maintenance** works, especially repainting of rusted iron or steel frames without thorough removal of existing paint layers and surface rust. As paint ages it cracks and delaminates, often trapping moisture when exposed to rain or leaving the metal surface vulnerable to oxidation. Existing paint layers also need to be taken out to enable thorough rust removal. Furthermore, **overpainting**, or successive building up of paint layers, will obscure decorative details and affect the appearance of these feature doors and windows. It may also distort the shape and profile of the door or window frame, or reduce the spacing at joints, causing the door or window to become jammed and inoperable.

Cast iron components break and snap off more easily compared to steel or wrought iron, being less ductile and more susceptible to shearing force. On the other hand, wrought iron and steel gates tend to warp and twist out of shape upon impact.

Far left: *Peeling paint and rust corrosion of prewar galvanized steel military garage roller shutter at former Beach Road Camp.*
Left: *Long-neglected mild steel window with extensive corrosion, deteriorated beading, missing glazing, accumulated debris and broken ironmongery found at Capitol Theatre prior to rehabilitation works.*

For copper-based materials such as bronze, unlike iron oxidation or rust, copper patina forms a protective layer for the underlying metal and is prized for its aesthetics. Organic stains from animal droppings and inappropriate patching may, however, damage the patina and metal.

A common manmade damage causing loss of heritage character and value is the expedient removal and replacement of historic mild steel windows with aluminium frame windows, citing lack of available skills and materials. In fact, there are local specialist metalwork builders who are able to carry out conservation repairs, source for matching salvaged materials and even produce replicas.

Common symptoms and defects on metal doors, windows, grilles and gates to look out for include the following:

- **Oxidation and corrosion.**
- **Failing beading and sealant, broken or dislodged glazing** that needs to be replaced to ensure weathertightness.
- **Constant exposure to moisture and corrosive conditions** such as from ponding, leakage, droppings (acidic), cement stains (alkaline), etc., that may lead to further deterioration.
- **Improper welding** often leads to corrosion and broken elements.
- **Exposed fasteners**, including bolts and nuts, especially in moist conditions may corrode over time or due to galvanic and crevice corrosion.
- **Failing paint and coating** meant to impart protection to the metal surface. Mechanical abrasion due to usage, particles, water and so on over time may wear off the surface protection layer, leaving the core material vulnerable.
- **Joints between parts or with other structures** where differential thermal expansion may cause fatigue failure, creep and stress-induced damage.
- **Compromised operation** of movable parts that may be due to dislodgement, corrosion, overpainting, debris etc.

Right: *Overpainted cast iron fencing with defects at joint between units – dislodgement, corrosion, inappropriate ad hoc welding patch repair.*
Far right: *Historic metal gates at Bukit Brown Cemetery – corrosion and breakage at lower edges that tend to receive impact and are exposed to ground moisture.*

Most local historic metal doors, windows, grilles and gates would have been originally finished with some form of protective coating or paintwork. In such cases, **paint stratification, pigment composition analysis** and other investigation of the coatings, and detailed documentation if needed, should be carried out prior to any interventions.

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

NON-DESTRUCTIVE TESTS

Non-destructive tests (NDT) on historic metal doors, windows, gates and grilles are usually for identifying metal types and assessing the thickness and condition of protective coating such as paint and galvanizing layers that may not be apparent from a visual inspection. These can be carried out as part of frontline investigation where results will inform the conservation work scope, methods and material specifications. NDTs may be done in situ (or on-site) without the need for dismantling these elements:

- **X-Ray Fluoroscopy (XRF)** – the handheld version may be used in situ to determine the type of metal.
- **Magnetic pull-off gauge** measures the thickness and types of coatings by gauging how much these affect the attraction (pull-off force) between a permanent magnet and the targeted ferrous member. This test is sensitive to the surface roughness, curvature, substrate thickness and type of metal alloy.
- **Eddy current techniques** are used to measure nonferrous metal substrates and the type and thickness of non-conductive coatings on top, via their respective effects on the magnitude of the current generated. This test is sensitive to the surface roughness, type and shape of the substrate.
- **Ultrasonic technique** is capable of measuring the thickness of multilayer coatings, such as paint and galvanized layers applied on the substrate, by analyzing pulse signals sent through the coating and reflected by the substrate.

Ornamental detail and condition of historic clan house gates obscured by thick overpainting – NDT can provide an initial assessment of the underlying metal condition and the thickness and types of coatings.

SAMPLING AND LABORATORY ANALYSIS

- **Microscopic inspection** can be used to detect minute discontinuities and defects on metal. On-site microscopy may be carried out, though the study will be limited by the magnifying power of a hand-held microscope. In the laboratory, optical and scanning electron microscopy enable much closer inspection of the surfaces to determine types and extent of damage and defects, and to analyze microstructure.
- **Metallography analysis** is a specialized microscopic study carried out to determine the microstructure composition of metal. Preparation is needed in the form of a polished sample mounted on an epoxy resin block. The sample is then treated with acid to reveal the microstructure of the metal, impurities, grain size, stress fracture and other defects, to be examined and analyzed under the microscope by specialist metallurgists.

Microscopic imaging at different magnification showing corrosion extent and microstructure of an extracted stainless steel sample.

Conservation, Intervention and Maintenance

Refer to *Chapter 6, Ironmongery*, for the conservation intervention of door and window accessories such as hinges, handles, locksets, stays, bolts, levers and so on.

Refer also to *Volume 4 Structure, Chapter 4 Metal Structures, section on Structural Repair and Rehabilitation*, for more details on cold stitching and welding techniques.

Apart from conservation intervention on the metal elements, for long-term protection, root causes such as moisture, abrasion and galvanic corrosion must be properly diagnosed and resolved.

Copper-based materials such as bronze may be cleaned using a soft brush of natural material, low-pressure water jet to remove stains, and non-ionic soap only where necessary. The surface should then be rinsed and inspected for active corrosion. Anti-corrosion **benzotriazole** may be used but only with extreme care and protective measures in place, as it is a known carcinogen. Final protective treatment is then carried out by coatings of **wax, varnish** or **lacquer**.

Aluminium-based material is in general softer and should not undergo abrasive treatments such as sandblasting. It may be washed with chemical cleaners, though strong alkaline or acidic cleaners should be avoided. The appropriate cleaner and method depends on the specific aluminium production, alloy or finish and should be derived through trial cleaning. Once cleaned, it should be protected by coatings of **wax, varnish or lacquer**.

In some cases, iron or steel is coated with zinc in a process known as galvanization. As zinc oxidizes more readily than iron, it forms a protective sacrificial layer which corrodes first when in contact with air and water.

Ferrous material – removal of paint, rust and residue should be carried out using the appropriate method for the specific material and finish, usually sandblasting and wire-brushing, to a near-white finish. A **zinc-rich primer** should then be applied immediately after as a protective layer cutting off contact with air and moisture.

Recoating for ferrous metals may be carried out using polyurethane, epoxy, alkyd and zinc silicate paint, depending on the historic finish or colour to be reinstated. Application can be done by roller, brush, spraying, air spraying and so on.

Filling may be done to even out minor surface defects such as cracks and holes using a suitable metal filler, prior to application of the final coating.

Restored cast iron feature window with foundation plaque and Singapore Volunteer Corps coat of arms at the SSVF HQ.

Original and replica mild steel pivoted windows at the former Brittania Club (later NCO Club). Reinstatement using replicas was done for window locations where the original had been demolished.

Cold-system mechanical keyed repair method, or **cold stitching**, is recommended for cast iron repair of cracks or attaching broken or replacement parts. Profiled grooves are created across the line of breakage and then keys are driven into these grooves to stitch the two sides together. This is carried out at regular intervals depending on the extent of damage, material and component.

Welding, where the base metal is melted by high heat and cooled to fuse, usually with an added filler, is used for repairing cracks on wrought iron and steel structures.

Localized replacement is done for components that are missing or corroded beyond repair, including ironmongery, using salvaged historic parts or purpose-fabricated replicas of similar design, if these are no longer regularly made or available on the market. For partially damaged members, the defective section should be sawn off and the replacement parts welded on for wrought iron and steel, or cold-stitched in the case of cast iron. The same specific metal type should be used for partial replacement or repair materials and fasteners to avoid bimetallic corrosion.

Reinstatement of elements that are missing or severely damaged beyond repair is preferably done using dismantled historic elements of similar design from other parts of the same building, or architectural salvage yards. Alternatively, small-scale **replica fabrication** by specialized foundries may be possible, through detailed study of the component build-up, profile, joints, installation methods and other construction details of the original historic element, adapting to available manufacturing equipment and developing prototypes.

4 GLAZING

Overview

Refer to *Volume 3 Facades, Chapter 6 Cladding, and Chapter 7 Glass Blocks*, for the closely related history, deterioration, diagnostics and conservation intervention of glass claddings and glass blocks.

In the early handblown cylinder method, the molten glass 'balloon' had to be swung mechanically in a trench to stretch the cylinder to the desired shape and length. This was highly dependent on the skill of the glass worker and produced glass of differing thickness and sizes. In the early 1900s, new machine-drawn methods enabled production of larger cylinders. Cylinders of glass were extruded vertically from a 12m-high cylindrical iron tank, before being cut and flattened into sheets.

The use of glass in architecture is primarily to allow light to enter and views out while protecting the interiors from climatic elements. Coloured and patterned glass may also be used selectively for decorative or symbolic purposes. This chapter focuses on glazing that is found on doors and windows, including fixed lights – or openings with fixed glazing – usually found above or beside openings.

Glass as a building material gained traction with the invention of sheet glass production in the Industrial Age. Early **sheet glass** was produced using the **cylinder method**, where melted mixtures of silica sand, soda and lime were handblown into long cylindrical balloons; the ends of the cylinder would be cut off, and the cylinder would be cut lengthwise, reheated and flattened onto a cast iron table. Patented in the 1830s, glass manufactured in this manner was largely imported from Europe to Singapore, up until the interwar years.

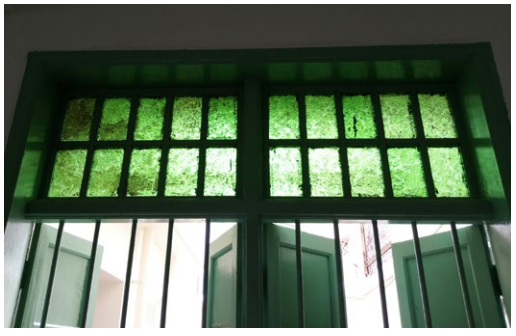
Early Shophouse Style	First Transitional Shophouse Style	Late Shophouse Style	Second Transitional Shophouse Style	Art Deco Shophouse Style	Modern Shophouse Style
Shophouses of this style are shorter and have one or two timber windows on the upper storey facade. The early builders made use of locally sourced construction materials. Plaster ornamentation is minimal.	With increased wealth and an influx of skilled labour, shophouses became taller and decorated with plaster and tile. Addition of small panels of glass into the timber windows became increasingly common.	This is the most spectacular style, particularly in the extensive use of plaster, tile and cast iron ornamentation. Each upper-storey facade has three windows with minimal wall in between for maximum ventilation.	Shophouses of this style are simpler and more streamlined as builders began to cut down on the use of ornamentation, perhaps as a reaction to the exuberant spirit of the Late Shophouse Style and to the economic situation of the time.	The Art Deco style is typified by streamlining of classical motifs such as column orders, arches and pediments into geometric designs. A common feature is a plaque with the date of the building's construction. Shanghai plaster was also a popular surface treatment.	Common features are the innovative use of thin concrete fins and air vents which are functional as well as decorative. Flat roofs became the norm. Mild steel windows complement the geometric facade.

Shophouse window glazing through the years: *Prior to the 1900s shophouses/townhouses mostly featured timber shutters without glazing. Glass was then used sparingly as a decorative feature, often coloured and patterned, in the form of lattice toplights and window vision panels. Larger glazed areas became common from the interwar years when glass became more affordable and available.*

This window (below) of a historic bungalow features a glazing piece with ripple-like undulation known as a 'bullseye' that is likely crown glass. Glass blown into a 'crown' or hollow globe is flattened into a large flat disk by centrifugal force, and cut into the size required. The glass is thinnest towards the edge, with bullseye being the thick center area around the pontil mark (where a metal rod tool was attached to the hot glass in the glass blowing process).

Due to the limitations of the production method and inherent strength, early sheet glass tended to be produced in smaller sizes, and it was expensive to glaze entire window openings. For this reason, up to the 1920s, windows here were typically timber frame infilled with solid timber panels or louvres, and rarely glazed, as can be seen on the early shophouses. Only civic buildings, or buildings of the affluent, could afford any form of glass in their windows – these were often limited to areas such as toplights, for purpose of lighting up deep rooms, and feature windows on the main facade of the building.

Developments in glass manufacturing of the early 20th century led to glass becoming increasingly affordable to the masses. In 1914, the first Japanese manufacturers succeeded in replicating the European cylinder sheet glass process, vastly relieving the demand for expensive European imports. Concurrently in Europe, advances in technology gave rise to the **rolled glass method**. Molten glass is first drawn upwards using cooled 'edge rollers' that lets the glass start setting, enabling it to be further drawn through machine rollers, producing larger flat sheets of consistent thickness. Embossed rollers were used to create **textured** and **patterned glass**.



Left: *By using embossed rollers, the technology of rolled sheet glass produced glass in a myriad of repeating patterns, such as the floral pattern shown here, which became so popular with the Straits Chinese that it is known colloquially as "Peranakan Glass".*
Right: *Green tinted embossed window glazing backlit by daylight, Teck Lim Road.*

Internationally, as glass featured more and more prominently on building facades, concern began to rise during this time over the effects of **glare and radiation** through glass windows on the health of the occupant. This prompted glass manufacturers to push out different forms of glazing technology to suit different concerns, such as film coatings, treatments for heat resistance, tinted 'actinic' glass to reduced glare and UV, etc. In addition, there were options to address **security** concerns, such as laminated glass and wired glass (glass inlaid with wire mesh). Improvements in manufacturing processes also produced glass with greater self-supporting strength that could span a wider expanse, enabling larger glazed areas on buildings.

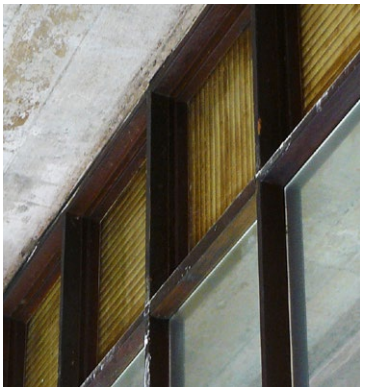
In spite of the sheer variety of options, demand for construction glass remained high – by the 1950s, Malaya was reported to be a veritably large market, drawing interest from manufacturers from as far as Poland, Britain, Japan and China.

In 1959, Messrs Pilkington Brothers, then one of the largest manufacturers of glass in the world, patented the technology for **float glass** – molten glass is floated in long ribbons on a bath of molten tin, flattened by its own weight. This technology, which is still being used to manufacture glass today, allowed the glass surface to be formed in a perfectly smooth finish, since the molten glass did not come into contact with any rollers in the process.

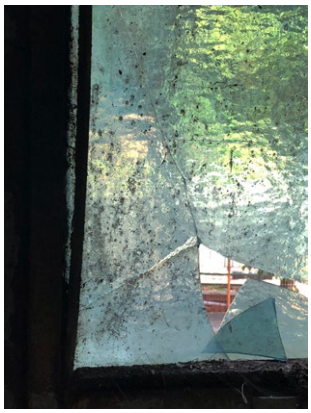
One of the earliest forms of double-glazing units (commonly known as DGU) was manufactured by Japan's Nippon Sheet Glass Co., Ltd. from the late 1940s, which was developed for thermal insulation and soundproofing. The firm set up its glass factory in Singapore in the 1960s.



From left: *Embossed rolled glass at shophouse in Geylang; Yellow tinted, and clear, glass with uneven 'crafted' texture at interwar period bungalows.*


Above from left: *Green tinted embossed glazing on mild steel windows, Chee Guan Chiang House (1939); Original fluted glass along top of timber screen, former Britannia Club (1953, aka later as NCO Club); 'Sparkle' textured glass, popular from the 1930s to 1970s.* ***Right:*** *Blue tinted textured glazing, large for its time, at former Tanjong Pagar Railway Station (1932).* ***Far right:*** *Fine grain cross reed textured glazing on 'Hope' brass windows, former George Street Telephone Exchange (1959).*

Top: *Breakage, staining and dislodged beading due to frame distorted from corrosion.* ***Middle:*** *Inappropriate replacement with mismatched glass type – the two panes on the right are original.* ***Above:*** *Damage to historic glazing by intrusive installation and inappropriate overpainting.*

Common Deterioration, Causes and Diagnostics

The condition of glazing and beading/sealant joints should be checked during regular half-yearly maintenance inspection of windows and doors by visual survey and even non-destructive techniques.

Broken or dislocated glazing and compromised beading or sealant joints may result in exfiltration of internal treated air to the exterior, and infiltration of warm external air as well as moisture. The former results in loss of energy, whilst the latter may lead to condensation, mould and algae growth, and water damage to historic interiors.

Laboratory tests – such as chemical analysis to identify the type of glass – are destructive as sampling is needed, but rarely necessary. Matching replacement glass can usually be identified by experienced historic glass conservators or suppliers.

VISUAL SURVEY

The most common signs of defects and deterioration are:

- **Fracture/breakage** due to stress of impact, fatigue, etc.
- **Abrasion** from wear and tear.
- **Discolouration** from dirt, pollution, weather exposure, etc.
- **Corrosion** by chemical attack such as strong acid and alkali often used in construction works.
- **Surface staining**.
- **Beading/sealant dislodgement and damage** from ageing material, weather exposure, frame distortion, etc.
- **Laminate damage**.
- **Recurrent condensation** indicating possible air leakage.
- **Mould and algae growth**
- **Inappropriate overpainting, repairs or modifications**, including replacement with mismatched glazing, boarding up, intrusive installations (e.g., air-con units, exhaust fans).

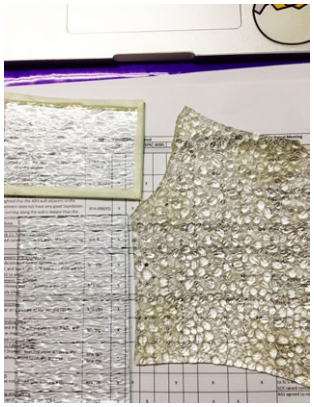
NON-DESTRUCTIVE TESTS

NDT are used mainly for detection of air or moisture leakage caused by defects that are not visible to the eye.

- **Infrared Thermography (IRT)** cameras detect the relative difference in radiation emitted by elements of different materials. The thermograms may show leakages of air around glazing as a different temperature from the rest of the facade. Trapped moisture within glazing may also be detected.
- **Ultrasound Leak Detector** is a highly sensitive tool for detecting very fine leaks around glazing and facades. A generator produces ultrasound on one side of the glazing, while the detector is placed at the other side near joints to pick up any ultrasound leakage.

The thermogram shows cold air leaking from the left window, likely due to sealant failure of the interior secondary window glazed panel.

Conservation, Intervention and Maintenance



Some glass manufacturers produce 'restoration glass' with imprinted textures that simulate historic glazing. Always examine samples of the new glass against the original, in order to find a close match.

Changes in manufacturing methods from the past till today have produced differing textures and colours of glazing, some of which may no longer be produced or would be difficult to replicate. For this reason replacement should be considered only if the glass panels are seriously damaged.

Before commencing work on your windows, it is important to **document** and map out the locations, types and conditions of historic glass in the windows of your building, to establish the intervention scope. Things to consider include:

- How many different types of glass are there, and which are historic?
- What types of defects are there, and which can be addressed by localized cleaning?
- How many pieces of glass are fractured, and how many are missing or inappropriately replaced and need to be reinstated?

Replacement glass material should be judiciously selected to match the historic in texture, tint and thickness. Historic glass that is out of production may be procured from salvaged yards, or cannibalized from dismantled windows or doors from other wings of the conserved building that will be demolished or modified.

CLEANING, MINOR REPAIRS, PROTECTION

- Any accumulated debris should be carefully removed.
- Worn-out or damaged sealant should be removed and replaced to restore air- and watertightness. It is not advisable to apply new sealant above worn-out sealant.
- Precious historic glazing with minor defects such as stains should be simply cleaned. While some stains may be removable using suitable chemical cleaners, irreversible defects such as fine scratches or discolouration are fine to be left as is.
- Historic glazing to be conserved in situ should be properly masked and protected when other construction and restoration works are ongoing to avoid staining and impact.

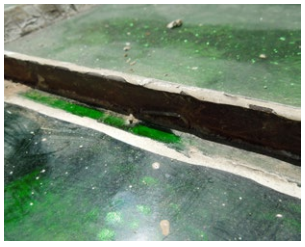
REPLACEMENT/REINSTATEMENT

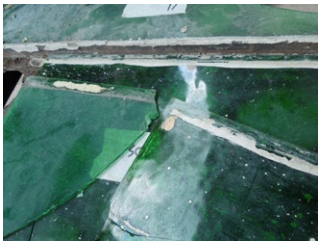
Preparation: Prior to removal, the edges of each glass panel should be taped to reinforce them against breakage. In many cases, breakage occurs during the restoration of windows due to careless handling of glass pieces. For this reason, works that pose a high risk of damage, such as the use of power tools, should be avoided. It is also generally a good idea to remove the entire sash/window panel for off-site dismantling, so that there is enough space for manoeuvring.

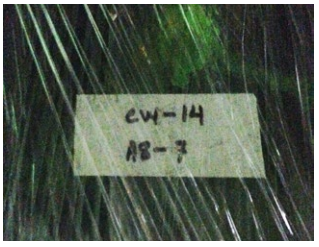
Taping the edges of glazing panels for protection prior to taking down the windows for dismantling the glass.

Removal: Methods of removal of glass depend on the construction of the window. The glass is then carefully wrapped, labelled and stored while the window frame is being restored.

TIMBER LATTICE WINDOW: *These should be dismantled in reverse order of their construction. Any beading should first be carefully taken out* ***(far left)****. Sometimes the bottom rail needs to be dismantled by removing fixing pegs, before the glass can be slid out.*







MILD STEEL WINDOW: *The glass is often held in place by an inbuilt clip, and then sealed off using a putty. To remove the glass, the putty needs to be* ***(from left)*** *carefully chipped off, revealing the clip, which is pried open to release the glass, followed by wrapping and labelling of intact removed glass for transportation to the storage location.*

Reinstallation: Once the window frames have been fully restored, the glazing can be reinstalled back into the original frames. Traditionally, gaps between the frame and glass are sealed using linseed putty – a blend of linseed oil and chalk dust.

To improve the seal and long-term performance, especially for steel windows, structural silicone has been used in some projects in place of traditional putty.

To prevent slipping during installation, a rubber 'stopper' can be placed underneath the edge of the glass.

If using structural silicone for steel window glazing installation, the glass should first be masked to prevent staining, allowing a gap for the joint, and the sealant applied by a skilled worker.

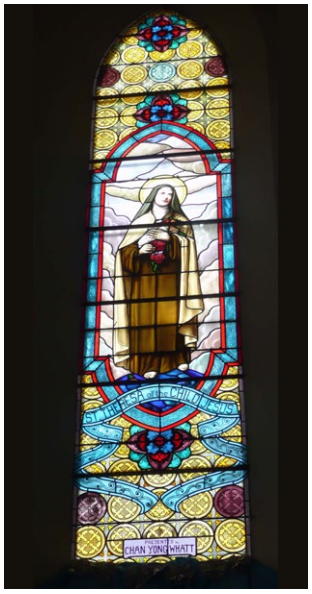
5 STAINED GLASS

Overview

Refer to *Chapter 4 Glazing* for information on the related history, deterioration, diagnostics and conservation intervention of door and window glazing.

In this chapter, the term 'stained glass' refers to the crafted arrangement of small pieces of coloured, enamelled and painted glass held together by strips of lead, supported within a rigid frame. It is sometimes known as 'leaded glass', which refers generically to all glass assemblies held in place by strips of lead, and the more recent copper or zinc.

The history of stained glass coheres with the architectural and ecclesiastical history of Europe. The earliest evidence of stained glass dates to AD540. Stained glass is characterized by the dynamic interplay between glass and light. Energized with light, stained glass changes with the time of day, the weather and the season. Handmade and often graced with painting, local existing historic stained glass windows are rare feature elements of high heritage and artistic value and should be treated with the utmost care.



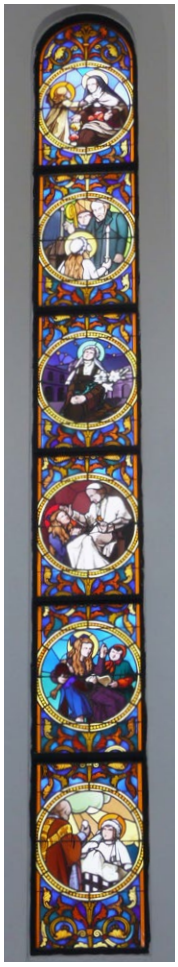
Figurative 'donor window' with donor name inscribed, Church of the Nativity of the Blessed Virgin Mary.

Stained glass in Singapore, as in other Commonwealth countries, is an inherited art-craft form. Its lineage is linked to the country's colonial past and thus has a short history compared to its European counterpart. Its emergence in Singapore, predominantly as feature windows in church buildings, is mainly to depict biblical narratives, embellish the church meaningfully, and/or commemorate prominent citizens and memorialize family members through the act of donation in kind.

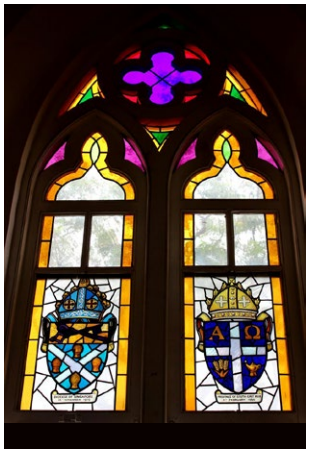
These stained glass windows reflect the religious, social and economic history of local communities. A rare surviving secular example of historic stained glass is the grand feature window at the Wellington House (1938).

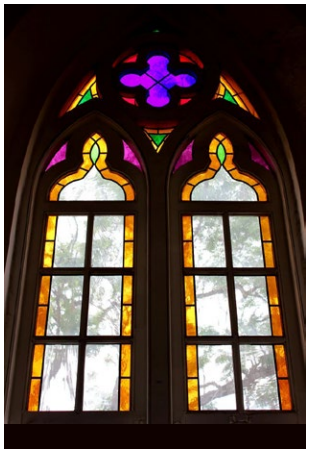
The earliest stained glass windows found in Singapore were European imports from studios in France, Belgium, England and Scotland. These were mainly commissioned by churches, with some paid for by families as 'donor windows' or 'memorial windows'. The **Dobbelaere stained glass studio** in Bruges, Belgium, supplied to many key churches including the Convent of the Holy Infant Jesus chapel (currently CHIJMES), St Joseph's Church, and Cathedral of the Good Shepherd. Historic stained glass windows in Singapore fall mainly into two categories:

- **Pictorial** or 'figurative' windows that depict biblical narratives and saints.
- **Ornamental** windows that carry **grisaille** or **geometric-foliated** work.



Left, right: *Figurative stained glass, and ornamental window, former CHIJ chapel.*





Below: *Rare surviving historic stained glass in a domestic setting, Wellington House.* ***Left and bottom left:*** *Stained glass window with paintwork of coat-of-arms, and without, St. Andrew's Cathedral.*

Above: *One of three triptychs depicting the life of St. Teresa, Church of St. Teresa.* ***Left:*** *Depiction of St Paul, Church of Sts. Peter & Paul.*

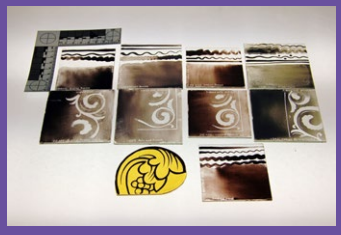
MAKING OF A STAINED GLASS PANEL

The basic steps of crafting a traditional stained glass panel are sketched out as follows:

- **A sketch is made:** A scaled-down design of the actual stained glass window or panel commissioned by the client after the theme and necessary details are finalized.
- **A cartoon is prepared:** A full-size drawing of the window or panel has all the relevant details to build the window, like dimensions, the lead lines, glass colours and artistic input.
- **A cutline is drafted:** The cartoon is replicated on tracing paper to become a 'working drawing'. The different glass pieces are separated by lead lines.
- **The glass is cut:** Glass of required colour and texture is selected to represent the design and theme. Glass is cut within the margins of the lead lines. The glass pieces are placed on the cutline of the design for final consideration.
- **The glass is painted:** Here, the colours are lent by the glass itself. The paint used is a form of vitreous pigment mixed with a binding agent. Special brushes are used to create different effects on the glass, like tracing, shading, stippling and matting. Stained glass windows may also be made with simply different types of glass and lead without any paintwork.
- **The glass is fired in a kiln:** Each time paint is applied on the glass, it undergoes a firing cycle to fix the paint permanently on the glass. Sometimes, the same glass piece undergoes several firings to lend the hues needed in pictorial windows.

Cartoon of a stained glass fanlight for the Cathedral of the Good Shepherd.

- **The glass is leaded:** The glass pieces laid out on the cutline are fitted inside the 'H' sections of the leads in a methodical way. Once all the glass and leads are assembled together, the joints or connections where lead lines meet are soldered with a special soldering iron on both sides of the panel.
- **The panel is waterproofed:** A special putty is prepared using calcium carbonate or whiting as a base among other ingredients and filled within the lead and glass spaces with a non abrasive brush. This process is done on both sides of the panel and is called 'cementing'. The panel is cleaned thoroughly post-cementing.
- **The panel is installed:** Appropriate framework for the stained glass windows – be it in steel, aluminium, wood or stone masonry – as well as correct installation method is the mainstay for stained glass windows.



*Above: **Glass before** (left) **and after** (right) **firing in a kiln.** Right: **Applying conservation putty to a stained glass panel to make it watertight and 'cement' the ensemble of glass and lead into place.***

***INSTALLATION** – Copper ties are soldered to the lead cames on the interior-facing side of the stained glass, and used for securing the panel onto supporting tie rods fixed within the wall opening.*

Common Deterioration, Causes and Diagnostics

Refer to *Chapter 1, General Notes on Maintenance and Common Issues*, for important concepts and issues to be aware of when taking care of historic fenestrations, and to take into account when planning for conservation maintenance.

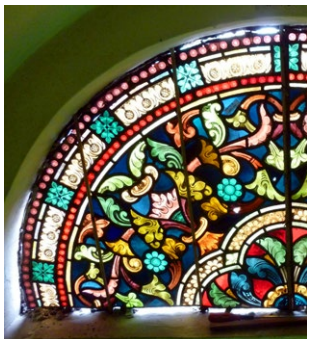
A stained glass window will never 'fall out' overnight. Stained glass windows should be checked half-yearly for early signs of defect by a properly trained and experienced inspector. Should problems be observed, an experienced and qualified stained glass conservator should be engaged, who can comprehend the degree of damage, diagnose the causes for deterioration and recommend appropriate interventions, some of which may be addressed in situ as conservation maintenance repair.

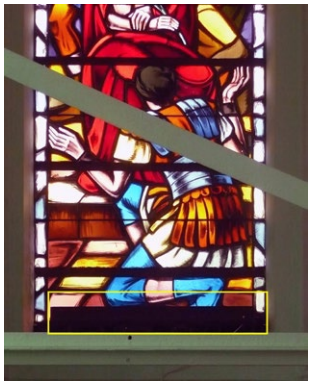
VISUAL AND TACTILE SURVEY

Each material that builds up a stained glass window plays a critical role in its survival and should be checked for common signs of deterioration during maintenance inspections:

Missing and broken glass pieces on stained glass window.

- **Glass quarries (panes):** This man-made, brittle material is vulnerable to breakage. Check for holes or cracks in the glass, any missing pieces, and dislodged or misaligned pieces from the lead.
- **Lead:** This material is by nature soft and malleable. It can age, lose its structural strength and sag, or get oxidized with pollution. Check if panels are beginning to bulge, bow and/or sag. Check also for any water ingress between the lead cames and glass.
- **Saddle-bars (tie rods) and copper ties:** The soft lead strips are soldered with copper ties that secure the stained glass panels to saddle-bars for support. Check for any damage of the rods and whether there are missing or broken copper ties.
- **Paintwork:** Poor rendering of paint on glass or incorrect or 'over-firing' of paint in the kiln may result in paint loss. Look out for fading, flaking or missing paint.
- **Mastic putty:** The putty might crack up or fall out of the leads it is meant to protect, exposing the stained glass window directly to the weather. Inspect for defective/missing putty and leaking windows.
- **Structural frames:** Poor or incorrect installation techniques weaken the stained glass window. Watch out for a window that has come loose of its setting or framework.





Top: *Past incorrect inside-out fixing causing damage to the stained glass fanlight.* ***Middle:*** *Bottom of stained glass buckling inwards* ***(near end)*** *and outwards* ***(far end)****, torn protective wire mesh, and fallen putty (accumulated debris on ledge).* ***Above:*** *Water ingress in a window.*

- **Secondary protective layer:** Sometimes a layer of secondary glass is installed as design enhancement, functioning as a protective measure or to achieve airtightness for air conditioning. However, due to the varying temperature and humidity with the use of air conditioner, condensation may occur between the stained glass and the secondary glass. Check also for any water ingress and ponding between the two layers.
- Check for **white efflorescence** (salt deposits) on any part of the stained glass window.

In order to comprehend the deterioration of a stained glass window at its root cause, and develop the appropriate conservation interventions, the following issues should be considered:

- What are the main problems in the window?
  - Is it buckled panels?
  - Missing glass?
  - Water ingress?
  - Fading paint?
- What are the causes that have led to these problems?
  - Is it incorrect fixing method?
  - Vandalism?
  - Humidity?
- What are the possible solutions to these problems?
  - De-stressing of panels?
  - Infill glass?
  - Fix fading paint?
- What are the possible solutions to the causes?
  - Redesigning a better framework?
  - Protective glazing?

Conservation, Intervention and Maintenance

Refer to *Chapter 1, General Notes on Conservation and Intervention*, for important concepts and issues to be aware of when undertaking conservation intervention works for historic fenestrations.

Comprehensive conservation intervention usually involves **dismantling, bench restoration and reinstallation** of the stained glass, a delicate operation that comes with some risk of damage and should only be carried out by a qualified, experienced stained glass conservator with a team of skilled artisans, well versed in historic stained glass techniques, materials and installation methods. It is pertinent to note that contemporary art glass techniques and materials are different and often inappropriate for conservation applications. This work should be carried out only for serious and extensive deterioration. Minor cracks, sagging and oxidation that are stabilised should be considered part of the character of historic stained glass, and require no treatment.

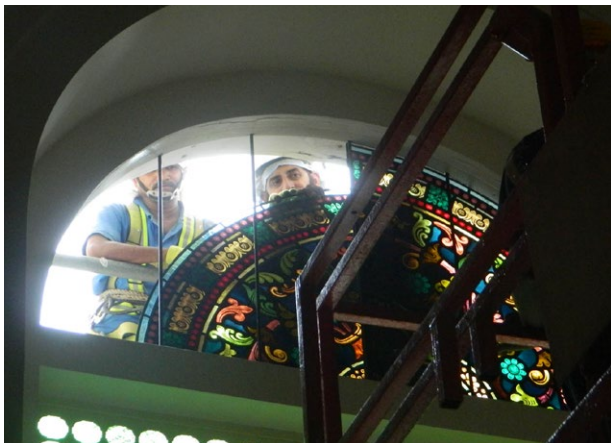
The conservator should begin with a thorough **documentation and pre-condition survey.** The documentation of historic stained glass should include particularly detailed photographic records of important details such as faces and hands of figures, insignias, memorial plates, signatures and donor names.

The conservator cuts exactly sized plywood mock-ups of each stained glass window – a fanlight in this case – marked with the locations of tie rods, to be provided to the builder to ensure a proper fit.

To develop **intervention strategies, methods and work sequence,** it may be necessary to consult other experts such as metal, timber and stone conservators, and even a historian, depending on the provenance of the stained glass, its installation and support methods or window frame materials, and their condition. Input from a conservation laboratory may be needed if environmental factors like humidity, surface temperature and wind velocity need to be monitored using specialist equipment for how these may affect the stained glass. The conservator should also be well versed with current thinking in timber, lime-plaster, steelwork, stonework and ventilation systems, to develop **design enhancements** that would ensure the longevity of the restored stained glass windows.

If the endeavour coincides with **major building conservation works**, the proposed interventions should be drawn up in consultation with the project team, especially the conservation architect/consultant, who should supervise key steps in the stained glass restoration process. It is also important to closely **coordinate with the various conservation trades**, such as a timber conservator working on the window frames, etc. In general, the dismantling of stained glass windows should take place prior to the start of major building works, while installation should be the second-last step of completion, to minimize risk of damage.

When building works such as painting are planned for nearby areas of the same site, the stained glass should be given adequate **temporary protection** beforehand, to prevent contact with harsh chemicals and detergents commonly used in construction that will cause irreversible damage.



Installation of restored fanlight by conservator team in accurately sized opening with tie rods prepared by the builder.

CONSERVATION MAINTENANCE CLEANING, REPAIRS

Stained glass windows have a long life expectancy, and a good maintenance programme will preserve the stained glass heritage for a very long time. It is important to maintain a log of maintenance and intervention works, as part of the **conservation documentation records**. These will provide valuable information to future caretakers and conservators and facilitate the continued care of the historic stained glass.

It is normal for stained glass to be covered with dust, dirt and grime over a period of time. Good and timely maintenance will enhance the longevity of a stained glass window. For **regular cleaning**, avoid water and simply dust the inside surface of the stained glass with a soft brush.

Thorough cleaning along with **specialist maintenance** inspection can be done once every five years by engaging a qualified and experienced stained glass conservator or restoration company. Such a specialist should be trained in removing surface dirt without compromising the stained glass fabric. Paintwork can be sensitive to acids in cleaning agents that can damage the historic, fragile pigments. Avoid using cleaning compounds and commercial detergents that contain acids, such as vinegar and ammonia, and never use abrasive, scouring powders or steel wool scrubbers.

Trial cleaning should be conducted at a discreet spot of painted area and proven suitable before application to the entire stained glass, using soft cotton cloth and a pH-neutral cleaning solution mixed with distilled water or professional-grade non-ionic detergent product. If the painted areas are found to be unaffected, this method can be safely applied to the rest of the painted and unpainted areas of the window. However, if the trial results in paint detaching from the glass surface, leave the dirt on the painted side untreated, and only clean the unpainted side gently with a soft, wet cloth.

If stained glass panels are installed using traditional mastic **putty** as infill between the lead strips and steel window frames, check for loose putty during regular inspections. Replace any fallen putty with conservation-grade putty.

If **steel ancillary supports** such as tie bars and 'T' bars have rusted, the rust build-up must be removed thoroughly, and the steel surface must be cleaned and repainted using at least two coats of epoxy paint.

Many historic stained glass windows were built-in with an outermost ring of unpainted **sacrificial 'break glass'**, designed to be carefully broken and removed for ease of handling when dismantling of the stained glass is called for. The break glass should be reinstated if 'sacrificed' during dismantling, or may be introduced if found missing, as an added protective measure to minimize accidental damage in future conservation works.

Reinstating perimeter break glass.

CONSERVATION INTERVENTION

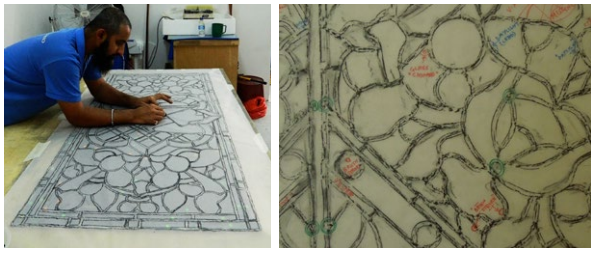
Depending on the extent of damage as assessed by the stained glass conservator, the bench restoration process may involve thorough cleaning, minor repairs such as replacing copper ties, missing/damaged lead repair, missing/damaged glass repair, painted artwork restoration, and 'cementing' the stained glass ensemble with conservation putty.

Minimum intervention: Retaining all historic stained glass material in good condition is the primary concern. Localized repairs can address minor defects if surrounding lead and glass are in sound condition. For example: complete re-leading of a window is not necessary if lead matrices are in good condition.

Badly compromised lead cames are dismantled, and localized lead replacement is carried out.

A crack through a major painted glass piece is repaired using string lead, rather than replaced.

Comprehensive recording: Photo-documenting all processes and stages involved in restoration, and detailed tagging of each panel, are important for both the conservation process and future reference. It is good practice for custodians and conservators to have in-house records of all repairs and restorations undertaken in their projects. For example: labelling of panels within a window that have a repeated pattern will facilitate refixing in the same order, post-restoration. Rubbings of the stained glass are also made prior to any bench repair.



Rubbings serve as a one-to-one documentation of the lead and glass ensemble, base drawing for marking up defects and proposed repairs, and reference template for creating replacement lead and glass pieces.

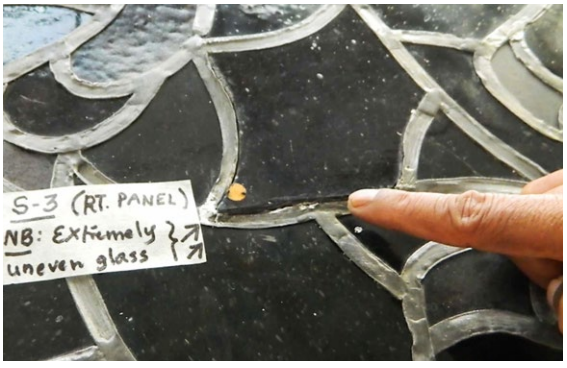
Tagging of dismantled or dislodged elements of the historic stained glass.

Reversibility of techniques: Repair and restoration approaches undertaken should be reversible as far as possible. This allows room to adopt better techniques in future interventions, if required, and ensures reversal of errors.

Like-for-like restoration: It is important to closely study the installation method and support system of the stained glass window, and maintain the original fixing methodology. Restoration materials should also match the historic in performance and visual/physical characteristics, such as the glass type, thickness, texture, and tint. Painted artwork that needs to be restored should be restored by trained artists in matching style and technique to the original.

Above: *Types of lead used for conservation, and matching the profile of replacement lead type with the historic.*
Right: *Restoration artist painting on new glass pieces for reconstruction of a missing painted quarry.*

Design enhancement: Where there are inherent issues in the original method or materials causing deterioration, design enhancement or a compatible replacement may be considered.



Right: *Early handblown glass often has uneven thickness – overly thick pieces may lead to localized stress in the lead matrix.* **Far right:** *For maximum retention of historic material, instead of replacement, such pieces may be carefully released from the lead cames and put to the grinder for tapering their thickness, before reinstalling.*

PROTECTION

There is no ideal way to protect stained glass windows from their natural ageing process, especially in the tropical climate of Singapore that has regular rainfall and high humidity. Nonetheless, the introduction of an external protective layer may be considered to mitigate any **direct physical contact or impact**, such as from the weather elements, stray branches, vandalism and so on. Many early stained glass windows in Singapore were protected with wire mesh (based on the European model) – this allowed the windows to be ventilated, unlike an added layer of glazing. Installation of any form of protective layer should be discussed with the stained glass specialist and conservation consultant before execution and should adhere to any regulatory requirements. Basic requirements for the protective layer include:

- Gap of minimum 50mm from the stained glass.
- Ensure ventilation and air flow around the stained glass.
- Does not affect the heritage presentation/visual appeal of the stained glass.
- Types of protection, design and materials used should be sensitive and compatible to the historic building and stained glass design.
- Maintenance-friendly.

Following are some of the current-day options available.

Stainless steel wire guard: Welded wire mesh to modern-day specifications of AISI 316 stainless steel, 12 gauge in diameter, 75mm x 12mm spacing, 6mm diameter support rods for the perimeter, is a well-tested specification. Some disadvantages – may be visible through the stained glass internally, allows dirt, debris and rainwater to penetrate, and requires regular maintenance especially to clear away accumulated debris.

Early type wire mesh protection.

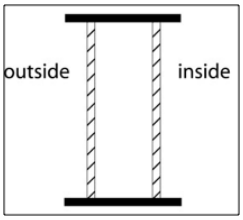
Acrylics or polycarbonates: Polycarbonates should be preferred over acrylic, and 8-12mm thickness is adequate depending on the size. These materials, including Perspex, are easily available, cost-effective and lightweight. Some disadvantages – these materials will yellow and lose transparency gradually with exposure to sunlight, are prone to deformation and scratches, and have a relatively short lifespan, requiring frequent replacement.

Glass: Different types of glass can be used – commercial float, tempered or toughened, laminated. Glass offers the clarity required to view stained glass, can be cut to required shapes, and has longevity. Some disadvantages – may be easily breakable (in the case of float glass) and heavy in weight especially for large glazing.

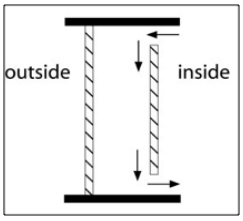
Installation of new external protective glass layer.

Isothermal glazing: Apart from an external protective glazing layer, a gap is maintained at the top or bottom of the stained glass. This effectively ventilates the interstitial space, keeping the temperature on both sides of the stained glass window the same, and greatly reducing condensation. However, it should be devised in consultation with a conservation specialist, and subject to on-site trials in the actual microclimatic condition before implementation.

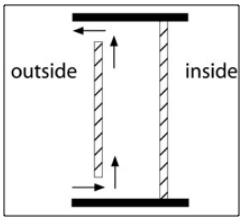
TYPES OF ISOTHERMAL GLAZING SYSTEMS



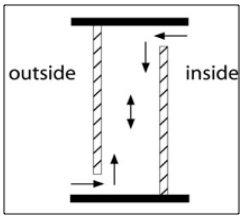
Non-ventilated system



Internal ventilated system

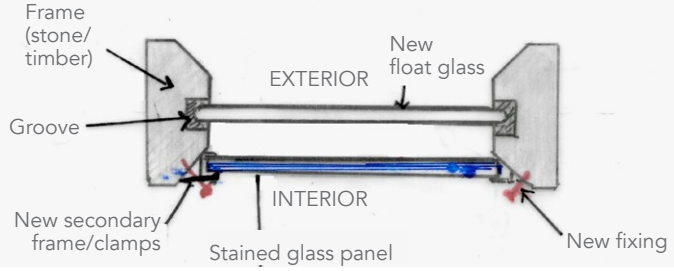


External ventilated system



Mixed ventilated system

SKETCH DESIGN FOR INTERNAL VENTILATED GLAZING

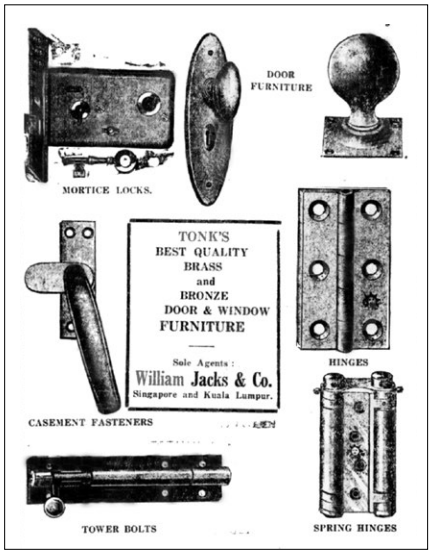


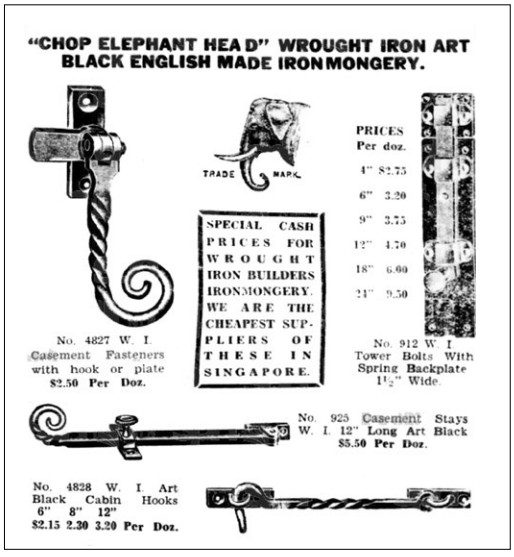
6 IRONMONGERY

Overview

Architectural ironmongery, also known as architectural hardware, refers to (mainly metal) accessories for doors and windows such as handles, hinges, stays, closers, doorstops, bolts, locksets, rails and so on. These elements experience constant use, especially those with moving operable parts, and are usually designed to be highly durable. Historic ironmongery also serves as aesthetic features that add visual and tactile interest to the heritage experience.

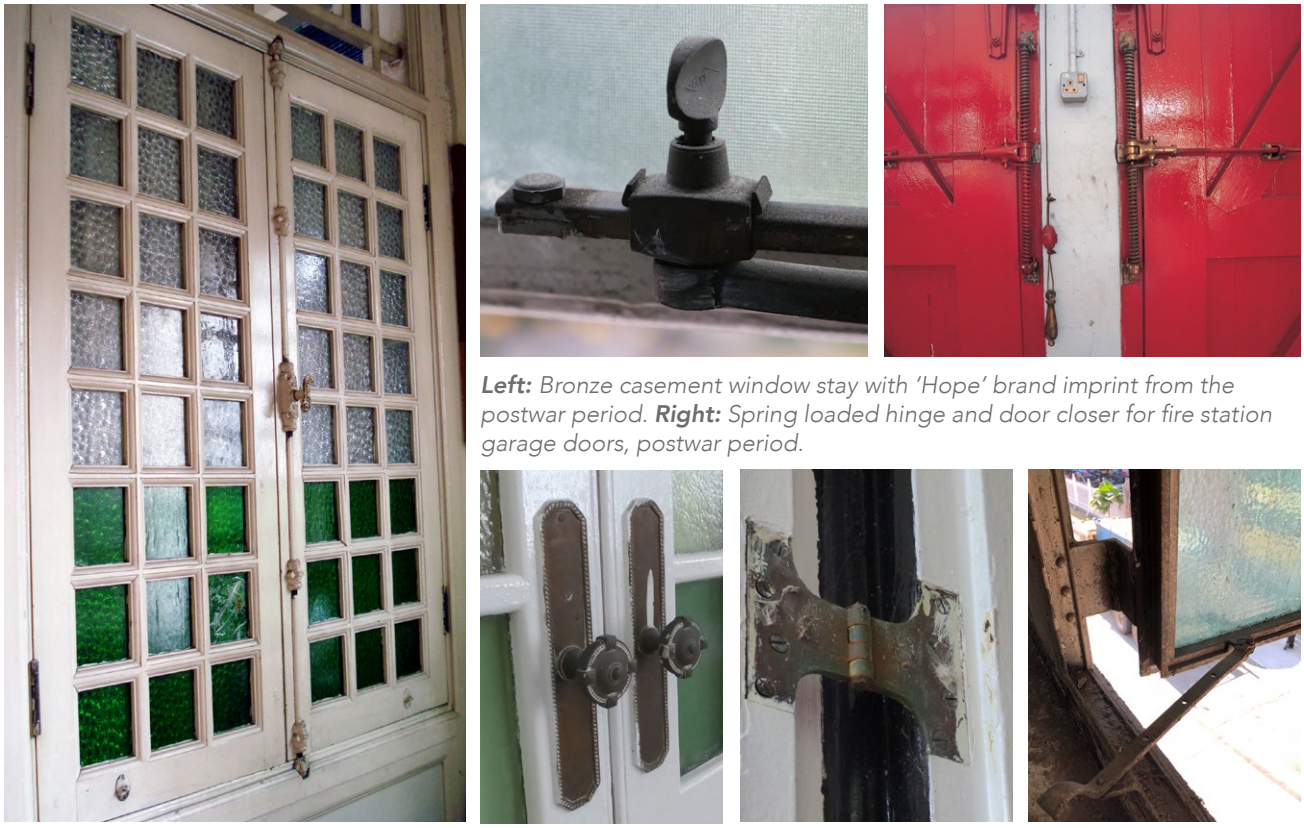
Most prewar historic ironmongery found locally was supplied by overseas metal foundries and imported to Singapore, such as the 'Tonks' brand manufactured in Birmingham, England. Early locally made examples include fittings that come with mild steel windows, produced by pioneer local manufacturer United Metal Works since 1933. Most ironmongery dating from the prewar era were made of hard-wearing bronze or brass that gained a characteristic patina and sheen with use, with the occasional wrought iron samples featuring more ornate designs. With technological progress in the manufacturing process, ironmongery also came to be made in steel and aluminium, more widely used from the 1960s–70s onwards.





*Archival advertisements of British imported ironmongery made of brass and bronze **(right)**, as well as wrought iron **(far right)**. Double spring hinges that allow for opening inwards and outwards are often found on historic pintu pagar swing doors.*

Left to right: *Heavy duty gate hinge for large, hefty cathedral doors, possibly in wrought iron and dating to 19th century; Bronze casement fastener with 'hook' detail; Long tower bolt for securing heavy doors; Bronze window operation lever with crank for opening and closing clerestory windows from the postwar period.*



Left: *Bronze casement window stay with 'Hope' brand imprint from the postwar period.* ***Right:*** *Spring loaded hinge and door closer for fire station garage doors, postwar period.*

Left to right: *Cremone bolt, designed to lock or unlock both top and bottom latches at the same time with a single twist of the lever knob; Entrance brass doorknobs with backplates; Bronze butterfly hinge that allows for 180 degrees opening angle; Mild steel casement window and ironmongery that are installed as a set.*

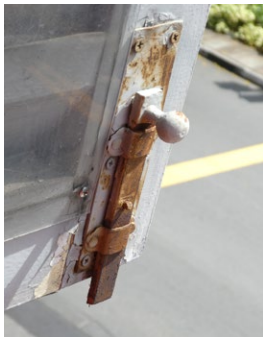
Common Deterioration, Causes and Diagnostics

Refer to *Chapter 1, General Notes on Maintenance and Common Issues* for important concepts and issues to be aware of when taking care of historic fenestrations, and to take into account when planning for conservation maintenance.

Designed for durability, most historic architectural ironmongery should have a long lifespan with regular use and adequate maintenance. Unfortunately, like the doors and windows they are attached to, many are under-maintained and often expediently replaced when minor defects occur, or to suit changing tastes.

Diagnosis of these elements typically involves **tactile and visual survey**. Corrosion of ironmongery may result from **galvanizing corrosion** arising from two different metals in direct contact – this may occur if fasteners such as screws were replaced in ad hoc repairs using a different metal from the historic ironmongery.

Another common issue is inappropriate **overpainting**, resulting in thick layers that obscure details and even affect the mechanism of operable ironmongery items. Unless they were originally plated or factory-coated, ironmongery should in general be left in its **historic metal finish** after cleaning and repairs. Protection of ferrous ironmongery items that undergo less wear and tear, such as railings, may be considered for protective painting.



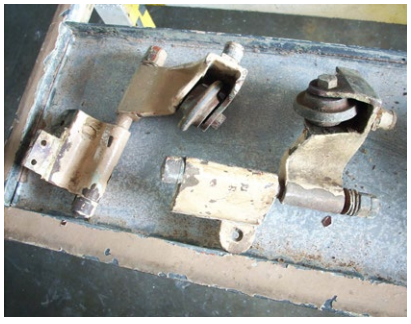

Left to right: *Corrosion of window tower bolt; Overpainted, jammed and dislodged butt hinge; Casement fastener with hook handle bent out of shape; Overpainted barrel hinge with mismatched screw fasteners probably from past inappropriate replacement.*

Conservation, Intervention and Maintenance

Refer to *Chapter 1, General Notes on Conservation and Intervention* for important concepts and issues to be aware of when undertaking conservation intervention works for historic fenestrations.

The principle objective of conservation intervention and maintenance repair is to arrest deterioration, restore mechanism operations, as well as reinstate historic design and finish. If the doors, windows or ironmongery items need to be **dismantled** – such as for paint removal – thorough and detailed **documentation** of each item or part should be carried out. The ironmongery fixing and assembly method should be carefully studied and dismantling/disassembly carried out manually to avoid damage. Each part should be labelled and documented accordingly.

In conserving and maintaining ironmongery, care should be taken to retain the **natural patina**, especially in decorative features. Aggressive cleaning methods, including high-pressure air with abrasives and laser or chemical cleaning is neither advisable nor necessary. **Overpolishing** is a common maintenance malpractice that may result in loss of relief details and heritage/aesthetic value of the historic ironmongery.



Top left: *Careful manual dismantling of historic butt hinge.* ***Top far left:*** *Dismantled roller hinges of a top hung sliding-folding mild steel door.* ***Bottom:*** *Dismantled and disassembled ironmongery for documentation, cleaning and repair of each part before reassembly and reinstatement.*

Cleaning may be carried out using neutral soap with thorough rinsing and drying. Damaged mechanical movable parts should be repaired using matching and compatible material. For **ferrous items** (wrought iron, mild steel), rust residue may be removed by copper wire brush; fine grit sanding and chemical stripper may be considered for paint removal following trials. For **copper-based items** (bronze, brass), gentle polishing should be done with lint-free cloth using nonabrasive metal polisher. Paint may be softened and removed by hot-soaking the ironmongery parts in a solution of baking soda or mild detergent, using a nylon brush to remove more stubborn stains.

Maintenance: Movable parts require regular cleaning and lubrication. Periodic gentle polishing will extend the life of ironmongery. However, take note to protect and mask any sensitive surrounding finishes and materials during cleaning and polishing. After polishing and cleaning, apply a layer of microcrystalline wax followed by buffing to protect the surface.

For **reinstating** missing or inappropriately replaced ironmongery, similar salvaged ones from other parts of the building or salvage yards may be used. There may also be commercially available conservation ironmongery products. Otherwise, **replicas** may be commissioned, using surviving intact original items elsewhere in the historic building for production reference.

*Original top hung casement fastener **(left)** and a replica **(right)**. Working within the limits of the metal workshop, the replica is made with a simplified profile that can be distinguished upon closer scrutiny, but bearing sufficient likeness to the original to allow for a coherent heritage presentation.*

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.

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 Institute of Architects of Malaya, The Malayan Architect*
Government records:	Building plans, Annual Reports of Public Works Department/Municipality/ Singapore Improvement Trust

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Tan, Ian
Page 38 (left, middle); 39 (top row middle); 42 (right); 43.

The Glass Studio
Page 58; 59 (left top, left middle & bottom, right top); 60; 61 (top row); 70 (all); 63 (top & bottom); 67-68 (all); 64.

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Other archival sources
Crown Colony of the Straits Settlements Public Works Department Annual Report (1938): Page 18 (left).

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