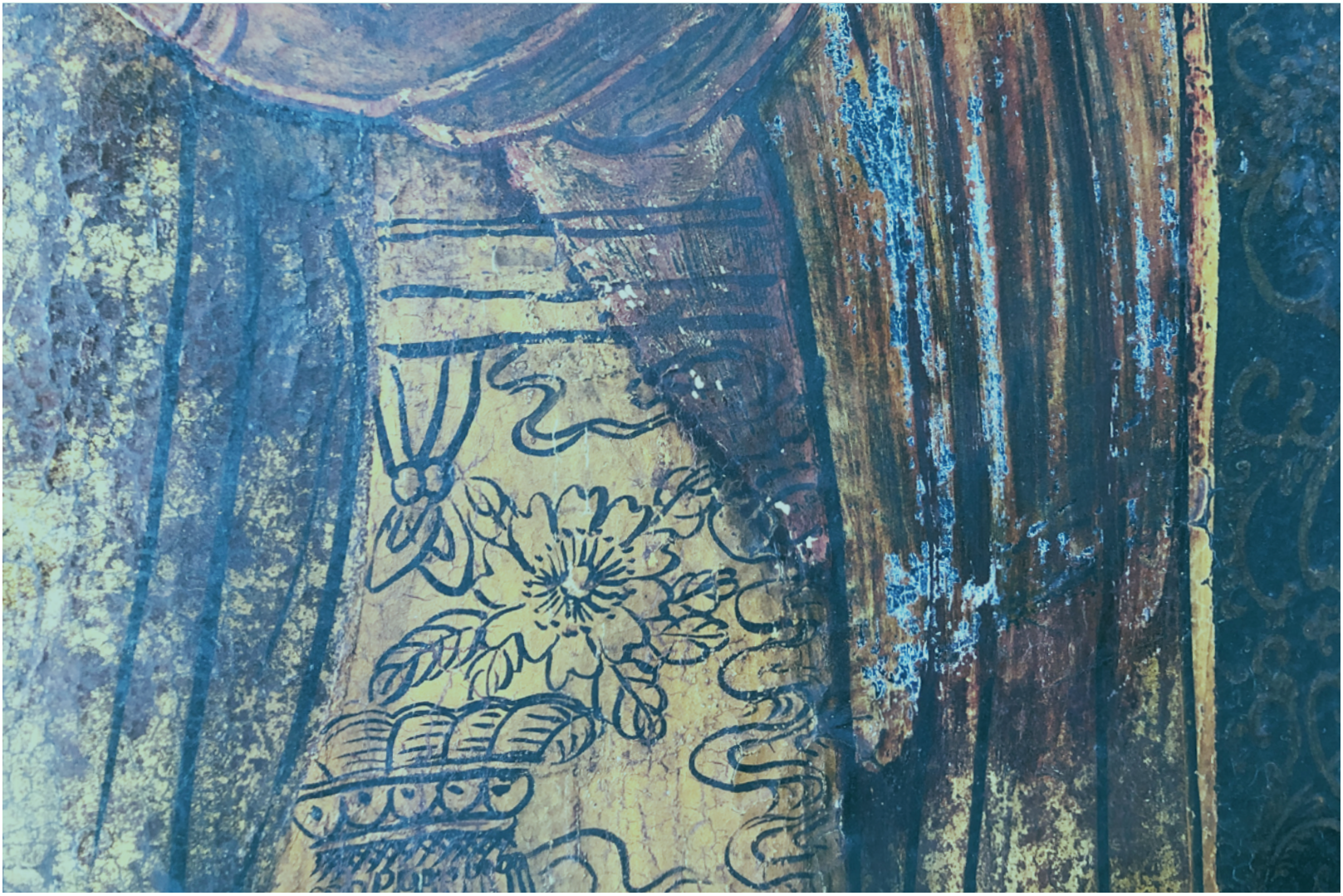
CONSERVATION TECHNICAL HANDBOOK

A GUIDE FOR BEST PRACTICES

Volume 7 | Paints and Coatings

ICOMOS SINGAPORE

URBAN REDEVELOPMENT AUTHORITY



Conservation Technical Handbook
Volume 7 | Paints and Coatings

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URBAN REDEVELOPMENT AUTHORITY

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Cover photograph courtesy of Studio Lapis:
Detail of weathered door god painting on timber doors at main entrance of Thian Hock Keng Temple.

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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
Founding President (2014-2019)
ICOMOS Singapore

About This Volume

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

What do the icons mean?


General tips and advice


Concepts learnt in other chapters or volumes in the series


External references


Further reading and topical notes

Volume 7: Paints and Coatings is the seventh book in the **Conservation Technical Handbook Series**. It focuses on finishing paints and coatings used historically on buildings in Singapore, including limewash, oil-based paints, mineral silicate paint, waxes, varnishes and lacquers. Key challenges and principles in the conservation, intervention and maintenance of these historic paintwork or painted artwork are also addressed, including indoor environmental issues and malpractices.

While advanced technical investigations and works would require specialist consultants and contractors, the Handbooks provide decision makers and other stakeholders an overview of what constitutes good conservation/maintenance practice and basic understanding of the underlying principles, that will hopefully inform better building management and works planning for the historic property.

Chapter 1 Introduction establishes the heritage, artistic and social significance of architectural paints and coatings. It covers common terms and basic concepts of paint components, systems and application. A selection of common local historic paints and coatings is presented, with discussions on their local supply and production, and how or why these came to be used in particular ways in Singapore's past building practices. The chapter addresses common long term care and maintenance issues for paints and coatings. It lays out the broad approaches and guiding principles for the best conservation and intervention practices, to be underlined by a rigorous process of paint research, diagnostics and analysis.

Chapter 2 On Plaster focuses on the care, conservation and application of paints applied on plastered surfaces and elements, including mural artwork. Historic colour trends on building facades and interiors are also discussed.

Chapter 3 On Timber and Metal looks at paints and coatings for timber and metal building elements, including the distinctive colour scheme of 'black and white' bungalows, and the art of timber gilding.

The contents of each chapter are organised under these key headings:

Overview: The chapter begins with the application trends of paints and coatings on the particular substrate material (plaster, timber or metal) in the past, and where these could be found in historic buildings, illustrated by examples.

Common Deterioration, Causes and Diagnostics: This section presents the common defects and issues to look out for and their likely causes, as well as the key investigation and diagnostic methods. Both simple visual and tactile methods of diagnosis as well as specialist investigations are outlined.

Conservation and Intervention: The last section outlines appropriate ways of conservation and intervention, from paint stripping, cleaning, to repair and repainting.

1 INTRODUCTION

Common Historic Coatings and Conservation Principles

Overview

In the larger scheme of building conservation, historic architectural paints and coatings are usually given a low priority in the local context. This may be partly due to the tropical environment that tends to wear down coatings more rapidly or poor maintenance practice. More often, it is due to a low awareness of the heritage significance of historic coatings and colour schemes, and the prevailing perception that these finishing coats should match current tastes and trends. It is not uncommon for historic coating layers to be expediently removed without documentation, resulting in irrevocable loss of heritage value and knowledge.

In fact, like other key historic elements, the material composition, application method, and design/colour schemes of these finishing coatings embody architectural, social and material history. They provide significant evidence of the building's original function and occupants, and the relevant periods' construction practices, material production/ supplies, artisanal culture, and social and aesthetic trends.

Following paint removal, a historically significant hand-painted sign was uncovered in the Church of St Teresa, indicating the original location of a donation box 'For the Poor'.

GUAN KIAT & CO., LTD.

(Incorporated in Singapore)

35, PHILLIP STREET.

NEW STOCKS ON HAND.

Baker's Preparation or Soldering Fluid
Rabone's Boxwood Spirit Levels
½ in. Whitworth Thread Taps
Lewis Berger's Ready Mixed White Paints
Hubbuck's Fine Ground White Lead
Hubbuck's Genuine Dry Red Lead
Stapled Mixed Hair Broom Heads
Burnt Turkey Umber in Powder,
etc., etc., etc.

***Left**: 1905 advertisement for Hall's Distemper, a ready-mix interior wall paint*
***Right**: Advertisement by importer for pigment in both powder form and ready-mix paints.*

Historic paints and coatings that comprise artwork, artisanal decoration and colour schemes established to be of heritage or artistic value should be considered integral to the building's material authenticity and heritage value. In particular, if these coatings and their substrate are in good condition and/or assessed to have exceptional value, they should be prioritised for conservation just like any other key historic element.

In functional terms, architectural paints and coatings are used as the finishing layers on built structures, serving not just to decorate and add visual interest, but also to protect and enhance material performance as part of the building system. During conservation and repainting, when the application or choice of paint and coating is incompatible with the substrate and/or building structure, it may cause the deterioration of these underlying materials.

Before mass production and technological advancement of paints took off in the 20th century, and the proliferation of **ready-mix products**, many professional painters made their own from basic components, procuring pigments and premixes from 'colourmen' or dealers to create **site mixes** from closely guarded 'recipes'. Prior to the invention of synthetic pigments, **mineral pigments** and **organic dyes** were the two sources of colour.

Common Terms

1914 advertisement for 'extra refined pale boiled linseed oil', touted as 'eminently suited' as a binder for preparing white paints due to its pale colour that does not turn yellow for 'considerable periods'.

Synthetic mineral pigment marketed by the Malaysian outlet of Lim Teck Lee Co. Ltd.

1929 advertisement for imported limewash disinfectant additive.

When referring to a paint component, '**organic**' implies that it has a carbon-based chemical make-up – and could be naturally sourced or synthetic. '**Inorganic**' components refers to mineral-based materials such as mineral pigments or silicate binders.

Paints and coatings are typically **liquid, liquefiable or mastic** compositions designed for application to a substrate in a thin layer with brushes, rollers and/or sprayers. **Paints** are pigmented and form an opaque finish. Other coatings such as **sealants, stains or varnishes** may be colourless or tinted with transparent colourant, depending on the constitution and function.

The key components of paints are the binder, the solvent and pigments.

- **Binder** – a medium that holds the pigments together, adheres the paint to the surface on which it is applied, and converts the paint to a solid protective finish as it dries out. Traditional binders include lime, clay and linseed oil, while natural or synthetic organic resins are the base material of most modern binders.
- **Solvent** – commonly known as 'thinner', this refers to a solvent or diluent that makes paint liquid, to enable even application. It is colourless, and evaporates completely as the paint dries out. Common traditional thinners are water and organic turpentine, while there is a wide variety of modern synthetic thinners.
- **Pigment** gives paint its opacity – or coverage – and colour, and usually works in combination with the binder to protect the underlying substrate. Historically, inorganic pigments are derived from earth minerals (ochre yellow, laterite red), stone minerals (malachite green), or synthetic mineral compounds. Natural organic pigments, on the other hand, come from plants (indigo blue) and animals (cochineal carmine).

There may be other **additives** to serve specific functions, such as **driers** (to quicken the drying of paints) and **fillers** or **extenders** (transparent components that add bulk and improve flow without affecting a paint's colours).

Paint or coating systems refer to the combinations of specific types of paint or coating applied in a certain sequence with each layer serving a particular purpose, designed as an optimal solution to protect the substrate from weathering and deterioration, and enhance its performance, while providing the desired aesthetic appearance. Such systems are broadly referred to by the number of coatings. Historically, it is common to observe three-coat systems applied on a range of substrates including plaster, timber and metal. A **primer coat** was used for the preparation of the substrate, to reduce porosity and even out surfaces, enabling efficient use and smooth application of paint for subsequent layers. An **intermediate coat** would then follow, to add thickness, further smoothen uneven surfaces and mask the primer coat that came in limited colours. Undercoats may also serve functional roles such as fire-resistance and rust-proofing. The **finishing coat**, being the exposed layer, served to protect the underlying coats and substrate from the elements, while providing the desired aesthetic appearance.

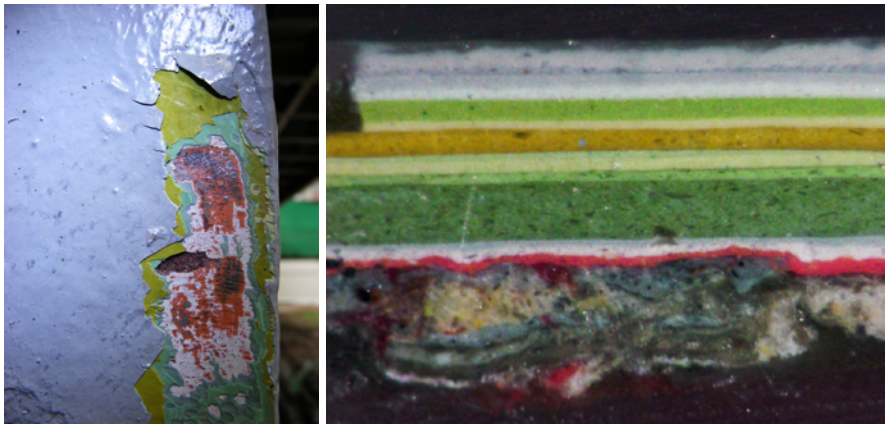


Photo and cross-section microscopic image showing paint layers of a cast-iron rainwater downpipe at Clifford Pier. The original paint system was likely a three-coat oil paint system, starting from the bottommost red coating applied directly on the metal substrate: an anti-rust red oxide primer coat, followed by a white intermediate layer, and a finishing grey coat – possibly tinted to match the original Shanghai plaster finish of the building facades.

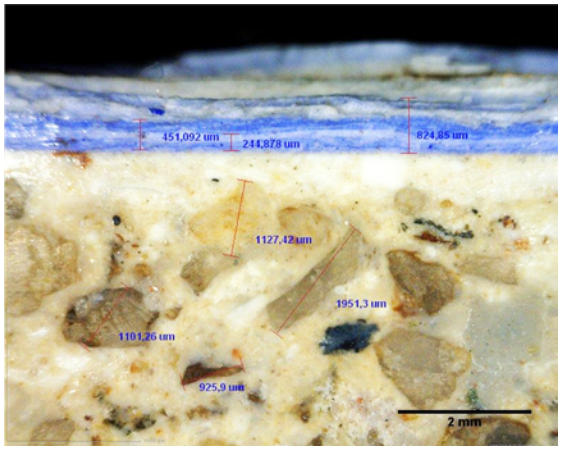
Common Historic Architectural Coatings

From a brief survey of newspaper advertisements up to the early 20th century in Singapore, many suppliers of exterior paints and pigments were also ship chandlers, provisioning colours for maritime repairs and maintenance. Their range of products would likely have included oil-bound pigments and commercial patented oil paints for use on marine timber and metals, as well as on buildings.

To date, formal studies into historic building paint and coating types used in Singapore remain limited; there is scarce documentation of past application techniques, site mix 'recipes', colour and usage trends. For heritage structures that are still standing to date, many have undergone multiple rounds of repainting and renovations where, more often than not, historic coating layers have been removed without prior analysis and documentation, leaving little trace of the original finishes applied.

Below is a quick introduction of selected historic mainstream paint and coating types used locally (with the approximate period of their local usage in parentheses). Traditional architectural coating types may be broadly differentiated as **water-based** or **oil-based** ones. Water-based paints such as limewash and mineral silicate paint may permeate or bind with the substrate and give a matt finish. Oil-based coatings include oil paints and varnishes, which tend to be film-forming with glossy appearances, unless specially treated to produce a flat finish.

Especially from the postwar period onwards, there was growing usage of modern factory-made coatings that are far more complex in chemical properties than their traditional counterparts, with an increasing proportion of synthetic components including alkyd, epoxy, acrylic, polyurethane, etc. A significant number of heritage buildings dating from the mid 20th century, or even earlier for some, would likely have been finished in some of these modern coating products.



Microscopic image of polished cross-section of a historic plaster sample, showing a substrate of lime plaster topped with several layers of limewash, a common historic coating.

Refer to *Volume 3 Facades*, Chapter 2 'Plasterwork', 'Overview' section, for a brief history of lime production and its building application in plaster render.

Around the end of the 19th century, municipal regulations were enacted that called for buildings to be regularly limewashed externally and internally. Sanitary officers were authorised to enter and inspect all premises and issue a 'Limewash Notice' which owners were reuired to comply within 48 hours or face prosecution.

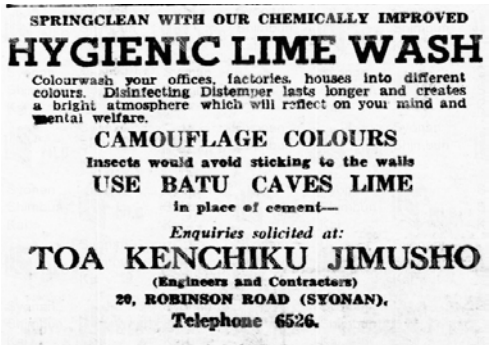
LIMEWASH (Before 1810s – 1970s)

Limewash was the most commonly used finishing coat for a wide range of local building types commonly applied on **lime plaster** on both exterior and interiors. Its use in Singapore likely dated from the pre-colonial era, till late 20th century. Variations of limewash could be found in the building tradition of the Chinese, Indian, British colonials and other migrant communities. Its popularity was also due to the affordability and availability of **lime**, locally produced by the colonial government as well as private kilns from the abundant **shells and corals** collected along the island coasts.

Usually site-mixed, limewash essentially comprises **slaked lime** diluted with **water** to form a thin milky liquid, that is applied with a brush. Its alkalinity also helps **sterilise** walls, and light tints can be introduced using alkali-fast mineral pigments or other dyes. Limewash tended to have a yellowish tint due to impurities from the natural constituents, and it was a common practice to add **ultramarine pigment** (usually the cheap synthetic version) for an optically brighter white final finish.

When applied, limewash penetrates into the substrate and hardens by the carbonation of lime with exposure to air. Limewash is vulnerable to pollutive environments and acid rain. It is usually reapplied every few years, though unlike mineral paint, it can be **layered on** without a need to remove old limewash coatings. It dries up into a **breathable** finish with characteristic soft tone colours and a matt, nuanced appearance.

Durability and water repellence, especially on external limewash, may be improved by adding **tallow** (animal fat), **drying oils** (such as linseed oil) and **casein**. Although water permeability is also reduced, it is still more breathable than most modern synthetic paints.



***Right**: 1922 advertisement for synthetic ultramarine pigment powder, commonly used as an optical whitening additive for 'Household Laundry, Dhobie, Paint and Colour wash work, etc'.*
***Far right**: 1943 Japanese Occupation period advertisement for limewash and distemper made from Batu Caves lime, also recommended for painting buildings in 'camouflage colours'.*

DISTEMPER (19th century – 1950s)

True distempers with their velvety, matt finish were favoured for indoor surface decoration paintwork. The low-cost coating comprised a **natural adhesive** (such as animal glue) as the binder and pulverised **lime** or chalk, mixed in water. It was sometimes sold in premix powder form as calcimine or kalsomine. Traditionally prepared fresh before application due to the short shelf life, different pigments could be added to create pastel 'colour washes', or ultramarine for a bright white finish.

Soluble in water, true distempers had low resistance to abrasion, could not be cleaned by washing, and were not recommended for exteriors or high-traffic areas. However, it was low cost, breathable and could be applied directly as a first coating on fresh lime plaster without the need to wait for the substrate to cure, allowing for significant time saved. It was also favoured as an **interior coating** which in one to two years' time could be easily brushed down, and reapplied in new colours or replaced with more durable paints. Being a coating that was meant to be removed before repainting, it was well-suited for **ornamental plasterwork**, where repeated overpainting would cause fine details to lose definition. Like limewash, distempers could be fortified for better durability and water resistance with proteins, waxes, oils or resins.

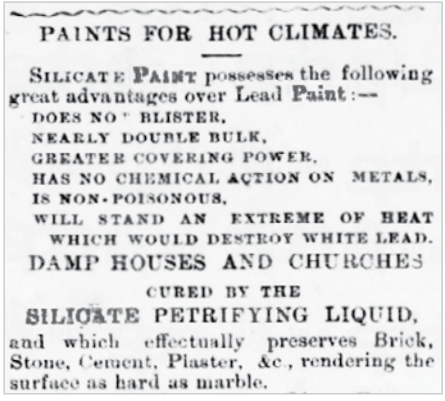
1929 advertisement for Hall's Distemper, used in the redecoration of the Raffles Hotel Dining Room.

WASHABLE OR OIL-BOUND DISTEMPER (1900s – 1970s)

Factory-made 'washable distempers' or 'oil-bound water paint' had been marketed in Singapore since the 1900s, touted as sanitary, durable, abrasion-resistant, suited for long-term and even exterior use, and could be painted on – unlike traditional distempers. A prominent brand was Hall's Distemper, recommended as being 'most suitable for Colonial work', and used in the repainting of Victoria Theatre and Raffles Hotel. These were in fact a type of **primitive oil-in-water emulsion paint**, with substantively different technical and chemical properties from true distempers. Critically, washable distempers were much less permeable than limewash or true distempers, irreversible, and produced a much thicker coating. 'Washable distempers' were eventually replaced by modern emulsion paints.

MINERAL SILICATE PAINT (from 1870s)

Silicate paints, containing **inorganic liquid silicate binders** and coloured with **mineral pigments**, were imported and sold in Singapore from at least the 1870s onwards, though it did not appear to be used widely – likely due to its high cost. Upon application, it penetrates and bonds strongly with the substrate to form a highly durable but breathable finish with matt, uniform appearance. It performs best when applied directly on the substrate. However, earlier coatings may have to be removed completely prior to application. Mineral silicate paints are also resistant to alkali and acid attack, and has good resistance to mould and algae. Today, modern versions are widely used for conservation projects.



PAINTS FOR HOT CLIMATES.

SILICATE PAINT possesses the following great advantages over Lead Paint:—

DOES NOT BLISTER,
NEARLY DOUBLE BULK,
GREATER COVERING POWER,
HAS NO CHEMICAL ACTION ON METALS,
IS NON-POISONOUS,
WILL STAND AN EXTREME OF HEAT WHICH WOULD DESTROY WHITE LEAD.

DAMP HOUSES AND CHURCHES CURED BY THE SILICATE PETRIFYING LIQUID,

and which effectually preserves Brick, Stone, Cement, Plaster, &c., rendering the surface as hard as marble.

1876 advertisement for silicate paints manufactured in Liverpool, UK, touted as 'Paints for hot climates', and recommended for 'Damp houses and churches'.

RUBBER PAINT

The 1920s-30s was a time of progress in chemical industries, experimentation, and innovation of new products – many short-lived – including paints. Local rubber producers looking to expand their market created **'rubber-bound paint'**, using the processed raw material as a binder. Likely the earliest local major building using rubber paint was Tanjong Pagar Railway Station (1932). According to newspaper reports on its opening, the building's interiors were finished in the new local paint product manufactured by Singapore Rubber Works, who also supplied the building's rubber tiles.

Singapore Rubber Works advertising their products, including rubber paint, 1922.

***Above**: Cement paint powder from the postwar era. **Right**: 1939 advertisement for cement paint sold in powder form to be mixed with water for use - formulated for 'exterior decoration and protection of concrete and plaster walls'. **Far right**: 1953 advertisement showcasing Parvinac, a "tropical emulsion paint" locally produced by PAR used on the then newly completed Pasir Panjang Power Station.*

CEMENT PAINT (1920s – 1970s)

Cement paint is a pigmented coating typically containing **white Portland cement**, calcium chloride, calcium hydroxide (hydrated lime) and gypsum. The resultant layer has some breathability, is able to withstand weathering and daily exposure, and has a soft speckled appearance. With the increased use and production of Portland cement in building works, cement paints soon became widespread and popular in Singapore from the early 20th century till the 1970s. These were marketed in Singapore with brands like Cementone (1920s-50s), Berger-tex (late 1930s-50s), Snowcem (1940s-70s), Permacem (1950s-60s), and Cempexo (1950s). In particular, these were used in the postwar years on government projects including Singapore Improvement Trust housing.

MODERN EMULSION PAINT (from 1950s)

Paints of stable vinyl or acrylic emulsions were developed with advancements in building chemical science. These became widely used from the postwar years and form the bulk of building paint today. A wide variety of formulations have been developed specifically for interior or exterior use, incorporating additives to reduce foaming, discourage mould growth or improve film-forming during application. Generally designed for modern cement plasters, emulsion paints are film-forming with low vapour permeability, and thus not suited for lime plaster substrate. Brands popularly marketed locally from the 1950s, with some dominating the market even today, include Britannia, PAR, Rapodec, Robbialac, Dulux Pentalite, and so on. Like cement paints, emulsion paints were used on postwar modern heritage structures, such as Pasir Panjang Power Station.

OILS AND WAXES (from 19th century)

Various types of oils have been used throughout history for making coatings, **linseed oil** being one of the most common, as well as **tung oil** (also known as China wood oil) in Chinese traditional paint mixes. These are known as **drying oils** or semi-drying oils that, when applied, form a continuous film through oxidation and polymerisation. On their own, these oils may be applied to timber for protection and maintenance, to refresh its finish. However, it should be noted that they harden and may become difficult to remove, and also naturally darken with age, changing the appearance of the element.

Beeswax and **microcrystalline wax** – a petroleum by-product first produced in the 1930s – are also used for protecting and maintaining unpainted timber surfaces and bronze elements.

OIL-BASED PAINT (from 19th century)

Colours can be added in the form of dry pigments and mixed into oils to create oil-based paints. These were applied on ferrous metal and timber elements, as well as plastered surfaces. **Lead-based oil paint**, typically comprising a base of white lead pigments in an oil binder – added with other pigments to create different colours – had been widely used since ancient history, until its toxicity was better established in the 20th century. Substitute pigments for use in paint such as zinc white and titanium white were developed in the 19th century; however, lead-based paint was still imported and used in Singapore up to the 1970s.

Today, under Singapore's Environmental Protection and Management Act (EPMA), lead is listed as a Hazardous Substance, with controls imposed on paints with a lead content beyond 0.06% by weight, as well as labelling requirements. Refer to the National Environment Agency's *Environment Protection Division Annual Report 2018*, Appendix 10 'List of Controlled Hazardous Substances', S/N 70.

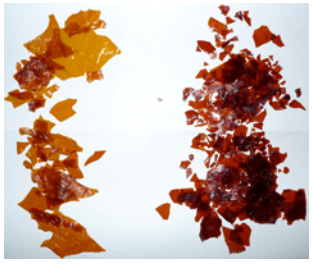
Left: *1930 advertisement for US-imported Sherwin-Williams paints and varnishes, that were used for the 'entire interior decoration of the Capitol'.* ***Right:*** *1929 advertisement for Wilkinson Heywood & Clark's, an imported brand of 'Genuine English' ready-mix oil paint.*

Amongst the earliest oil paints advertised by suppliers in the papers in mid-19th-century Singapore were brands such as Hubbuck's and Peacock and Buchan's. By the early 20th century, ads were also put up for Japanese brands of commercial zinc white, lead white and red lead like Nippon Paint and Flower Brand, etc. A pioneer of ready-mix oil paints, Sherwin-Williams supplied both paint and labour for the decorative paintwork of Capitol Theatre (1930). Natural resin varnish may be added to oil-based paint to create **enamel paint**, which dries to a characteristic hard, glossy finish.

VARNISHES AND STAINS (from 19th century)

Varnishes are traditionally a mixture of **natural resins, drying oils and solvents**. Often applied as a **protective film** on timber or paint finishes, varnishes are transparent and colourless. With the availability of synthetic resins for commercial use from the 1940s onwards, varnish coatings have been formulated from polyurethane and epoxy resins, which has resulted in faster drying and more durable clear films compared to coatings based on natural resins. Tinting pigments can also be added to make **stains**.

***Below**: Shellac flakes in two different shades.*
***Bottom**: The timber structures of many historic Chinese buildings are traditionally in daqi finish.*



SHELLAC LACQUER (before 1810s)

Shellac is a natural resin secreted by the female **lac insect** native to Asia, particularly India, where it is commercially farmed on a large scale. Sold as processed flakes, it is dissolved in alcohol to make liquid shellac, which has wide-ranging applications, including as a **wood primer, sealant, or high-gloss finish**. Following Europeans' discovery of shellac, it surpassed oils and waxes as the prevalent timber finish in the Western world for a period in the 19th century. Over time, the use of the natural resin was replaced first by nitrocellulose (a semi-synthetic resin derived from plant cellulose) and later by other fully synthetic polymer resins.

CHINESE LACQUER PAINT / DAQI 大漆 (before 1810s)

Timber structures and elements in historic Chinese houses – including Straits Chinese townhouses – and temples were often finished in daqi, a durable lacquer paint finish that is opaque, smooth, hard, and resistant to abrasion or corrosion. The coating is derived from the sap of the **lacquer tree**, which is treated to remove moisture and impurities, added with pigments, and traditionally bound in tung oil. During application, it is layered in several coats, and allowed to cure into a **hard, waterproof coating**, mainly used for timber.

Maintenance and Common Issues

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

Appropriate maintenance is required for painted or coated surfaces, with higher frequency of care needed for exterior paintwork. Consult the most updated conservation maintenance guide if available, or seek advice from a conservation consultant if needed. A proper maintenance regime should include:

- **Periodic cleaning:** It is important to only use cleaning agents chemically compatible with the respective paint materials, applied with suitable methods, for regular cleaning. Acidic detergent should be avoided for limewash or pigmented lime-based coating as it may cause etching damage. Highly alkaline detergent may damage alkyd- or oil-based paints. While common for maintaining newer buildings, high-pressure water jet cleaning should not be applied on historic building surfaces. Trial cleaning to establish the appropriate material and method should begin with pH-neutral agents (e.g., water) and non-abrasive/low-pressure methods. For interior surfaces, regular dusting or vacuuming will help prevent dirt build-up.

Scaffold being set up for shophouse facade maintenance cleaning, painting and repair works.

- **Periodic treatment and touch-up:** Protection and enhancement treatments are often essential to lengthen the lifespan of the paint and coating. The underlying paint or coating type should be established prior to selection of compatible surface protective treatment or touch-up coating type. If degradation from wear and tear is localised and not associated with any underlying moisture problem, it could be touched up simply by removal of the failing coating with a scraper and reapplication.
- **Periodic inspection and follow-up:** Regular visual inspection should be carried out to capture any anomaly of the paintwork. The distribution and severity of different types of defects could be mapped to establish any emerging pattern that may be indicative of possible causes. Expert advice should be sought especially for extensive or recurring problems, where further investigation may be needed.
- **Repainting:** The frequency of repainting depends on many factors including whether there is decorative artwork, the type of coating system, the quality of the previous paint job as well as the extent of exposure to factors causing deterioration such as weathering.

Common defects on paints and coatings may be due to various underlying causes ranging from environmental and wear-and-tear to accidental impact and inappropriate or inadequate maintenance.

A range of paint degradation observed in this interior space: moisture-related mould growth, blistering, delamination, etc. Buildings left vacant for long periods, or obscured areas (such as behind shelving, above false ceiling), often have aggravated deterioration due to lack of maintenance.

ENVIRONMENTAL FACTORS

In general, paints and coatings applied on **exterior surfaces**, being exposed to the elements, are subjected to more frequent and greater extent of damages. Environmental factors that tend to cause deterioration of coating materials, including **ultra-violet (UV) light, driving rain, vegetation, animal waste** and so on. **Pollutants** may also cause chemical reaction of components in the coating, leading to discolouration or breakdown. Historic building paints that are pigmented and hydrated lime based would be susceptible to erosion by excessive water such as heavy rain. Modern coatings that are primarily of synthetic components, on the other hand, may not be resistant to long-term exposure of UV-rays that cause photo-degradation, resulting in cracking, crazing and peeling.

Where there is close proximity to heavy vegetation, the **high humidity** would often lead to algae and plant growth, and prolonged moisture retention. Plants tend to grow in cracks or gaps in surfaces, leading to substrate and paint disintegration.

For **interior paintwork**, while there is more protection from climatic factors, there may still be other detrimental environmental causes. Presence of excessive humidity, for example in bathrooms or kitchens, is conducive for mould growth, which could infest and stain painted surfaces.

Left: *Faded and eroded painted mural relief on townhouse facade.* ***Middle:*** *Extensive mould infestation on shophouse five-foot-way ceiling painted timber floorboards, possibly due to excessive humidity or leakage in the room above.* ***Right:*** *The paint coat of an 1900 iron bridge subjected to exposed condition - weathering erosion and algae growth has led to paint flaking and rusting of substrate.*

INADEQUATE MAINTENANCE

Problems left undetected and untreated will worsen, and may become so aggravated over time that they are no longer treatable or irreversible damage has occurred. Stains from common contaminants and dirt such as algae and bird droppings may gradually penetrate into the paint surface and become difficult to clean. The contaminants may even be prone to water retention, or corrosive, leading to paint deterioration.

SUBSTRATE CONDITION

Paints and coatings are intimately related to their substrates. In most cases locally, coating conditions of historic buildings are assessed and interpreted as symptoms suggestive of underlying substrate problems. Conversely, where the historic paint coat itself is being considered for conservation, the substrate itself would also have to be carefully assessed for any defects, to be addressed as an integral part of paint conservation works.

Water seepage, rising damp from the ground, biotic and salt crystallization attack are problems commonly encountered in historic buildings that affect the substrate. When left unaddressed, the paint or coating layer will eventually be affected, leading to issues such as poor adhesion, chemical degradation, efflorescence and volumetric expansion of the paint or coating material.

For plaster, water seepage or rising damp may also cause deposits of water-soluble salts on or within the substrate - the salt crystal build-up will lead to friable plaster and ruptured paint layer (blistering and flaking).

Right: *Left unaddressed, the plant growth on this shophouse column capital has now caused deterioration to paint, plaster, and likely even brick substrate.*
Far right: *Paint with blistering, efflorescence and peeling arising from plaster substrate deterioration, which is in turn caused by roof leakage.*

INAPPROPRIATE WORKS

Building owners may carry out touch-up work to address problems, or periodic repainting exercise as part of the maintenance regime. However, inappropriate maintenance or touch-up may instead worsen the condition.

- **Root cause of defects unaddressed:** Applying new coats of paint over defective paint without addressing the underlying root cause will eventually lead to the resurfacing of the same problem, and failure of the new coat of paint.
- **Repeated overpainting** of elements with mouldings or reliefs will result in loss of legibility of fine details.
- **Inappropriate paint schemes** such as coating applied on originally fairfaced surfaces (e.g., brick, Shanghai plaster, stone, timber), use of insensitive colour schemes, painting over and obliterating historic murals, etc., will adversely impact heritage character, value, and presentation of the historic building.

Above left: *The recent red coat was applied over existing paint defects, which continued to fester and within a few months affected the top layer.*
Above right: *Repeated overpainting leads to loss of definition of ornamental details, obscuring important elements such as names, crests and mottos.*
Left: *Fine mural painted artwork panels crudely obliterated by overpainting, leaving only the scroll- and fan-shaped outlines in relief.*

Left: *Film-forming paint applied on historic shophouse facade results in extensive delamination, bulging, water retention and plant growth behind the unsightly 'loose skin' of coating.* ***Right:*** *Overpainted historic fairfaced bricks – the unbreathable coating not just obscured the original masonry but also caused its deterioration.*

- **Incompatible paint systems** are often used when there is no prior assessment of the existing paint and substrate constitution and condition. The use of incompatible paint systems or methods, including substrate preparation, often leads to aggravated issues. For example, the use of mineral silicate paint without first removing the existing emulsion paint will lead to detachment due to poor bonding between the two layers. Conventional film-forming paint systems, when inappropriately used, will cause retention of moisture when water ingress or rising damp occurs. As evaporation is unable to take place, both paintwork and underlying substrate will suffer from moisture-related damage, such as debonding of paint (bulging and peeling) or friable plaster.

RISING DAMP

A common problem in the humid tropical climate, rising damp in buildings refers to **ground moisture** drawn up by **capillary action** through building elements with ground contact. Historic constructions such as brick masonry walls with lime mortar joints finished in lime plaster and limewash allowed for moisture to escape via evaporation through these breathable finishes. However latter-day inappropriate practices often applied incompatible and unbreathable modern paints over the lime plaster or masonry walls, resulting in moisture retention. Salts carried by the ground water crystallizes and breaks down the plaster/masonry. Symptoms include efflorescence, friable plaster/brick, paint debonding and plant/algae growth.

Paint Analysis and Diagnostics

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

Consideration for the conservation and intervention of architectural paints and coatings should be included in the initial planning of any conservation projects, especially for relatively intact buildings where historic coatings are likely to be found. Advice should be sought from a qualified conservation consultant as to the heritage and condition assessment, diagnostic investigation and analysis, and recommended conservation approach. The conservation consultant will also be able to advise on the approach based on the timeline, budget and available resources.

RESEARCH, DOCUMENTATION AND PAINT ANALYSIS

In the **study, archival research, mapping and photo-documentation** of a building's historic elements, the paint or coating characteristics, including colours and any decorative artwork, should be recorded alongside the element's other attributes such as design, material and construction.

Research should include material history studies of **past colour trends**, pigment and other paint **material availability**, **application** practices, associated **symbolisms**, and so on, of the relevant period/s.

Archival studies may include old paintings, photographs, postcards, news reports, travel literature, etc., with visual depictions or text descriptions of **historic decoration schemes** and colours. Even for black and white photos, it is possible to glean important information such as which elements are highlighted in contrasting tones - for example, pale walls with dark door and window frames, and cornices picked out in middling tones.

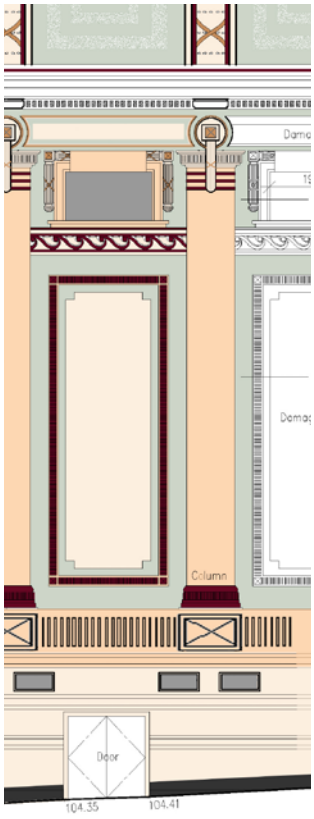
Painted surfaces with **fine art and decorative work** should be further researched and evaluated for dating, artistic significance, iconography and symbolism, and, if traceable, identification of the original artist or workshop and commissioning client.

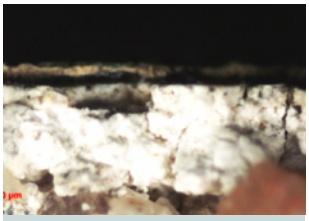
ARCHITECTURAL PAINT RESEARCH (APR)

APR is an emerging specialist field that is increasingly considered a critical component in key conservation projects. Detailed **sampling extraction and laboratory analysis of accumulated paint layers** are carried out, with the findings analysed in conjunction with historical **research** and archival information, to establish an interpretation of the **historic colour and decorative schemes** of a building, and even its construction phasing. Often, APR is undertaken to **inform decisions on the final paint scheme** of a building undergoing conservation works.

It also includes detail studies on **paint types and composition**, identifying potential issues and material incompatibility that informs the conservation approach and material.

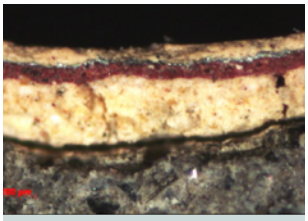
*Simulation of historic colour scheme **(below)** based on archival research and microscopic paint seriation studies **(right)**, with observed paint layers matched to Munsell colour code.*





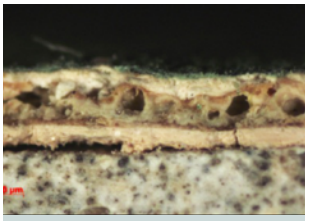
Sample: CT4

Total: 2 colours
1st: Green – 2.5 GY 6/4
2nd: Pale orange – 7.5YR8/4



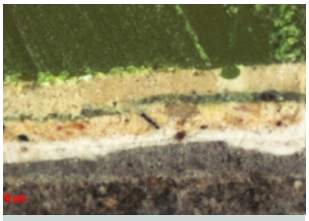
Sample: CT5

Total: 4 colours
1st: Orange – 7.5YR 8/6
2nd: Silver
3rd: Red – 5R 2/8
4th: Orange – 7.5YR 8/6



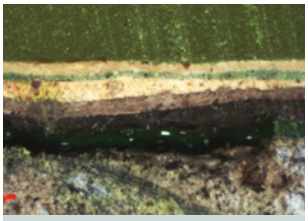
Sample: CT6

Total: 5 colours
1st: Green – 2.5GY 6/4
2nd: Pale yellow – 10YR 9/4
3rd: Orange – 7.5YR 7/8
4th: Brown – 10YR 5/2
5th: Pale orange – 7.5 YR 8/4



Sample: CT8 - flatwork

Total 3 colours
1st: Pale orange – 7.5YR 8/4
**Light green – impregnated epoxy*
2nd: Orange – 7.5 YR 8/4
3rd: Pale orange – 10 YR 9/2



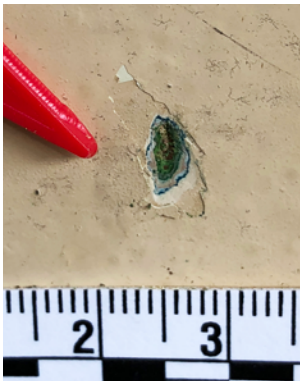
Sample: CT8 - moulded

Total 4 colours
1st: Pale orange – 7.5YR 8/4
**Light green – impregnated epoxy*
2nd: Pale orange – 7.5YR 8/4
3rd: Pale brown –7.5 YR 5/2
4th: Dark brown – 5YR 2/1

Paint analysis should be part of the heritage documentation process, and included in any paint conservation undertaking. There are two stages of investigation, namely paint seriation – identifying discrete coating layers and establishing their sequence – and chemical testing for material characterization.

For both, painted building elements of historic significance will first be identified, and the **sampling / testing location** determined by a qualified conservation consultant. Informed by historical research and field study, this should include a representative selection of elements in a range of materials including plasterwork, timberwork and metalwork, of different building phases, and spots that are likely rendered in different colours (For eg., both moulded and plainfaced areas of a wall should be selected for testing). The results could then be cross-verified with historical research and used to reconstruct the likely historic decorative scheme of a given phase.

Paint seriation: Basic in situ paint seriation methods include cratering and controlled paint stripping such as paint ladder or reveal, which are relatively primitive but quick ways to have a rough gauge of the underlying paint finishes and colours on site. In **cratering**, a sharp scalpel cuts through paint layers at a steep angle to the substrate level, is rotated to create a crater 2-3cm in diameter, and exposes the cross-section of accumulated layers. In a **paint ladder**, a selected strip of painted surface is masked, and applied with solvents of different strengths starting from the weakest, to progressively reveal individual coating layers as each 'step' on the paint ladder.



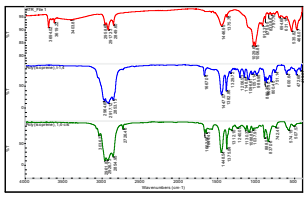
Right: *Cratering carried out on a historic timber door.*
Far right: *Paint ladder showing past coatings on a historic timber panel, including its carved moulding.*

Microscopic image of polished thin section prepared from extracted plaster sample, with historic coating layers identified and sequence numbered.

Sometimes a scalpel may also be used for mechanical scraping. This is repeated with each layer until the substrate level, while retaining a section from each revealed layer, so that a paint 'ladder' with each layer forming a 'step' is formed. If a layer is found with decorative artwork, a larger area of controlled paint stripping could be done to uncover patterns and motifs, etc. – a technique known as a **reveal**. The uncovered paint layers are then photographed with a colour-control and scale chart for record and further desktop analysis.

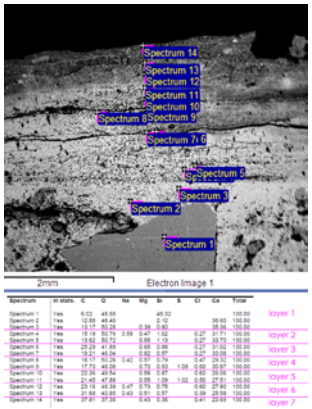
However, these basic methods largely rely on the naked eye, and thus may not yield sufficient details; some layers may also get damaged or mixed with another in the cratering or stripping process. For more definitive and detailed results, a **microscopic examination** should be carried out – a sample including all paint layers and the substrate is to be extracted, and a polished **thin section** prepared and mounted using laboratory equipment, and examined under a microscope.

The number, sequence, colour, physical appearance (for example, gloss or matt finish), thickness of paint layers, etc., could then be systematically established and documented in a controlled environment. Colour matching may be carried out using international colour code standards such as CIELAB, while taking into account limitations such as the effects of weathering, discolouration and dirt deposits, as well as the colour difference between paint surface and cross-section. References should be further taken from research on common colour schemes and paint compositions of the relevant period, locale, building type, etc.



The FTIR chart is analysed to determine the presence of types of organic and polymeric substance, which are clues to identifying the coating type.

Chemical tests for material identification: While paint seriation enables us to understand the sequential order of layers and colour of the historic paint system, chemical testing is required to characterize the paint materials. **Where suspected, the presence of hazardous materials like lead paint could also be tested for.** On site, some quick chemical tests could be conducted to distinguish the possible binder type of the historic paints. A number of common **chemical solvents** that could be used for this purpose include **diluted inorganic acid** to check the presence of lime- or cement-based paint, **acetone** to test the presence of organic synthetic resin, and **alkali** to check for oil-based paint. Interpreted together with archival research of the building and history of local paint use, the test results would provide preliminary indications of whether the tested paint layer is of historic significance. Detailed chemical instrumental tests could then be considered for more precise and detailed information of the identified historic paints:



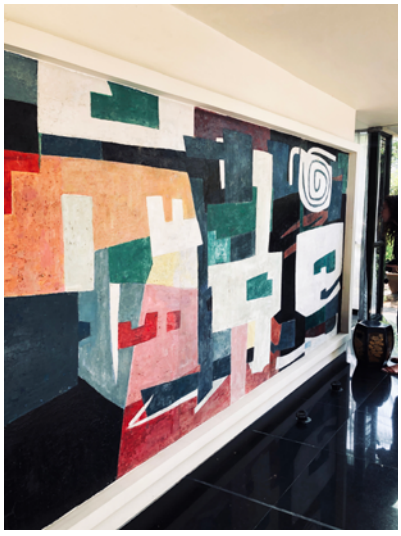
SEM image of paint thin section, with XRF results tabulated below showing detection of inorganic elements.

- **Fourier Transform Infrared Spectroscopy (FTIR)** is widely performed to determine the presence of organic and polymeric substances commonly found in different types of binders and other paint components, by identifying characteristic peaks of their molecular bonds.
- **X-ray Fluorescence Spectroscopy (XRF)**, available as a portable device for use on site, is deployed to detect the presence of inorganic elements in the paint composition. These include titanium (Ti), lead (Pb), zinc (Zn), silicon (Si) and other elements which might commonly be used in the pigment, additive or binder of historic paints, providing critical information such as the paint production period. For example, the presence of titanium (Ti) strongly suggests a 20th-century paint as titanium white only became available in the 1920s. However, this method needs a big enough exposed area for effective detection.
- **Scanning Electron Microscope (SEM)** and **Energy Dispersive X-ray Spectroscopy (EDX):** When more targeted detailed information such as the pigment or filler used in particular paint layers is needed, SEM coupled with EDX may be used in the microscopic examination of polished thin sections of paint layers. This allows the concentration and distribution of these chemical constituents within a paint layer to be closely studied.

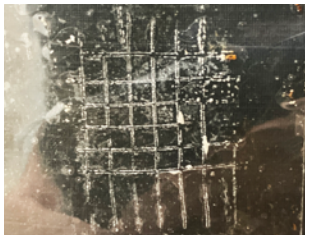
CONDITION ASSESSMENT AND DIAGNOSTICS

The paint conservation approach, priority and viability should be determined by considering the condition assessment result in conjunction with the heritage and artistic evaluation mentioned above. Paintworks of high heritage and artistic value should be prioritised as key conservation items, even if their condition may be highly deteriorated. For fine art and decoration work, tests that involve sampling or that may cause damage should be avoided or minimised at obscure locations.

Visual and tactile inspections should be first carried out to pick up any apparent **dilapidation issues**, and to establish their nature, cause, distribution and severity. In particular, coating defect patterns and damaged spots should be closely studied on site as a preliminary indication of material characteristic, and to observe if any underlying layers or substrate could be seen. A visual study by a trained eye may already provide critical information, such as the presence of prior coating layers, identity of substrate material, and detection of inappropriate paintwork - including whether this was originally a fairfaced element that was overpainted.



Left: *The white coating can be visually assessed to be a recent spray-on textured coating, chemically incompatible with and obscuring the original materiality of Shanghai plaster and cast-iron downpipe.*
Right: Studio, *a rare mural artwork by acclaimed pioneer local artist Chen Wen Hsi, found on a wall of his former house, exemplifies a painted architectural element of high historic and artistic value that is prioritised for conservation, notwithstanding its weathered condition.*



Top: Two-pin moisture meter being used to test the surface moisture of a coated timber floor.
Above: Cross-hatch adhesion test.

Equipment-based testing may sometimes be recommended by the conservation consultant for more detailed assessment of problem areas, as well as to uncover hidden issues. Many paint problems could be traced to moisture-related issues such as seepage and water retention in the substrate, which may not be visible to the eye. Three key tests often deployed for further assessment of paint condition are as follows.

- **Infrared thermography:** This non-destructive test (NDT) provides a quick global view of entire facades or large areas of exterior walls for detecting potential moisture retention issues of the substrate, or different materials that may have been concealed by overpainting.
- **Moisture check for substrate:** Relative moisture content could be assessed by in situ NDT. **Two-pin moisture meter** is for detecting surface moisture, while **capacitance-based meter** can provide moisture reading at greater depth. **Microwave moisture tomography** is able establish the extent and distribution of moisture at different depths within the substrate.
- **Adhesion test:** When there is adhesion failure of a coating to its substrate, its protective function is compromised. The existing bonding strength could be assessed by these in situ tests, which are usually destructive. A quick yet fairly reliable common method is the **cross-cut or cross-hatch adhesion test**, while another method involves the use of a **portable pull-off adhesion tester**. The latter enables the pull-off force to be recorded, and a more accurate measurement of the bonding strength. However, it may result in a larger area of damage that would need patch repair.

Refer to ASTM D3359: Standard Test Methods for Rating Adhesion by Tape Test, ASTM D4541: Standard Test Methods for Pull-off Strength of Coatings Using Portable Adhesion Tester and ASTM D7234: Standard Test Methods for Pull-off Strength of Coatings on Concrete Using Portable Adhesion Tester.

Microwave moisture tomography maps the distribution of wall moisture at different depths.

General Notes on Conservation and Intervention

Specialist artisan workshops with the needed skills and experience should be engaged to work on the restoration and reinstatement of painted fine art and decoration - architectural stained glass in this case.

SKILLS AND MATERIALS

The restoration of painted fine art or decoration should be carried out by qualified specialist workshops with artisans possessing good skills and knowledge in the relevant type of historic coating, iconography and artistic techniques, to ensure that the historic and artistic value will not be compromised. For more straightforward historic paint schemes, coating work or touch-up repairs, experienced and skilled painters or varnishers may be engaged.

In both cases, it is imperative to use compatible restoration or coating materials and application equipment/methods. In many cases of inappropriate restoration, the existing historic coatings or substrate become badly deteriorated but remain undetected under a new coat of paint.

TEMPORARY ROOF, PROTECTION AND ACCESS

Where the existing roof may be dismantled in the course of an extensive conservation project, a temporary roof should be erected to protect vulnerable interior finishes, including historic paintwork, from being exposed to the weather. The temporary roof also serves as a sun and rain shelter for artisans and fresh paintworks, enabling time-consuming conservation works to be carried out in most weather. Where possible, exterior conservation paintwork should be timed for periods of dry weather for sufficient application and drying time of the chosen paint system.

For in situ conservation paintworks, to prevent staining from paint dripping or spills, protection of surfaces or elements adjacent to or just below the target area, such as covers and masking, should be adequate and put in place prior to the start of work. Some of the elements may be installed at locations that are challenging to access, such as high ceilings and cornices.


Left: *Temporary roof protection during conservation works to protect delicate or vulnerable finishes from the elements.*
Right: *Paint removal using chemical stripper and manual scrapping during off-site bench restoration of timber doors.*

Though low cost and high strength, many chemical paint strippers contain toxic chemicals that are pollutive and harmful to the applicator if not handled properly. They tend to cause collateral damage to substrates or sensitive historic paint layers intended for retention. There are now more environmentally friendly and non-hazardous paint removal products in the market, these should be considered for use especially for conservation projects. Other methods to consider, depending on the substrate and paint type, include scraping, sanding, heat gun and low-abrasion blasting.

Conservation paintwork in areas with access issues such as multistorey facades, high ceilings, low headroom spaces, etc., requires careful staging and access planning.

CONSERVATION AND INTERVENTION STRATEGIES

Paint and coating schemes for conservation projects should not be decided solely on the basis of cost or the latest aesthetic or colour trends. They should be seen as a key heritage feature to be considered for retention or reinstatement, with the conservation approach informed by research and condition assessment findings, as detailed earlier. Qualified conservation experts should be engaged, from the assessment and devising of approach and policy, to the supervision and actual undertaking of works.

Existing paints and coatings found in a historic building, including underlayers, if assessed to be of historic value, should be fully documented and studied, including by paint analysis, prior to any works, to inform decisions on conservation approach and materials.

- **Prior conservation works**: The underlying substrate and architectural element should be cleaned, and any necessary repair and restoration (such as consolidation for plaster and wood, and corrosion removal for metals) carried out prior to coating works. In many cases, incompatible coatings would have to undergo **paint stripping**; depending on the new coating system, sometimes all layers have to be removed to ensure its proper adhesion to the substrate.

Left: *Rare historic mural relief of a conserved townhouse with relatively intact historic paintwork. Where there may not be enough resources for a full restoration, the historic artwork, even if deteriorated, should be simply retained and stabilised.* ***Right:*** *Crude, insensitive repainting resulted in vandalism of the mural relief artwork, and the loss of fine details, iconography and symbolic meaning.*

Given the sensitivity of coatings and paintwork, all conservation works on historic coating, such as paint stripping, consolidation, patching and so on, should undergo a **trial process** at obscure spots to test the suitability of method and material.

- **Retention - in situ or off-site**: Paintwork established to be historic and slated for retention may be conserved and restored in situ, especially on masonry walls or structural members. Some may also be restored off-site in a workshop following dismantling, cleaning and repair of the element on which the paintwork is found, such as prefabricated metal or timber building parts. Dismantling may be called for when more thorough work is needed, for example to repair deteriorated joints; however, it may cause damage to the historic paintwork as well as any surrounding building fabric. Highly valued paintwork that is assessed to be vulnerable to movement should be conserved in situ as far as possible. **Conservation** of historic paintwork may involve the following:
    - Controlled stripping of incompatible coatings or inappropriate past repairs
    - Cleaning of stains such as soot or droppings
    - Consolidation of flaking/deteriorated paint
    - Touching up or patching of missing paintwork
    - Application of a final protective coating
- **Reinstatement:** Paint conservation may involve reinstatement of historic paint schemes with new coating, especially where historic layers have been previously replaced or assessed to be unviable for retention (e.g., use of mineral silicate paint system that requires stripping down to substrate level). As detailed above, rigorous research, historic colour studies and paint analysis should be carried out to determine the historic paint scheme to be reinstated, and inform the paint type to use. Virtual simulation and mock-up of historic colour schemes should be carried out to test, assess and refine the envisioned appearance.

Right: *Mock-up of new colour scheme for historic interior – pastel green on flatwork, off-white mouldings, and warm grey stucco reliefs.*
Far right: *New mural on the plain side wall of a clan house depicting an imagined historic scene of activities taking place behind the walls.*

- **Selection of conservation paint materials** needs to take into consideration compatibility to the substrate material and condition, any retained existing paint material, and environmental conditions such as humidity and likelihood of abrasion. Any required specific function, such as mould prevention or reversibility, should also be taken into account.
- **Heritage presentation:** Painstakingly retained and restored historic paint or artwork, as well as historic colour schemes recreated based on rigorous Architectural Paint Research, should be given proper pride of place in the conserved building's overall scheme of heritage presentation, allowing for the full appreciation and enjoyment of these restored colours and painted features.
- **New colour schemes:** Where studies fail to arrive at the historic colour scheme, a new palette may proposed. However, this should not negatively impact on the heritage presentation of the historic building. For example, historic elements in **fairfaced finish** should not be painted over. Elements that would have been highlighted in a different tone or colour in the original colour scheme, such as fenestrations, architraves or cornices, should be similarly accented, instead of being 'blended' into the background wall colour. Paint and coating systems compatible to the substrate material should be used.
- **New murals** may be considered to enliven the historic building or streetscape, but these should not obscure the reading of the building's heritage elements and character; and should be confined to plain and non-sensitive elements such as side and back walls of shophouses. Paint and coating systems compatible with the substrate material should be used.

2 ON PLASTER

Overview: Historic Colour Schemes

Refer to *Chapter 1 Introduction, 'Overview', 'Common terms'* and *'Common historic architectural coatings'* for more information on basic concepts and common types of paint used historically in the local context.

Most of Singapore's urban heritage buildings are finished in plaster and paint. However, there has been limited documentation and study on historic building colour schemes in Singapore. The range of colours advertised in the prewar years provide a sense of the base colour schemes of the era – **zinc white, lead white, whiting (calcium carbonate), lead black, lamp (carbon) black, lead red, Venetian red, red oxide, brown oxide, yellow ochre, lead chromate yellow and ultramarine blue**.

Pastel shades, probably lightly tinted limewash, are widely viewed as the main historic colour schemes for prewar shophouses/townhouses with ornamental mouldings picked out in various shades. In a 2016-2018 Architectural Paint Research study of selected sampling and digital restoration of historic photographs of local historic buildings, it can indeed be observed that most of the external and internal walls tend to be of lighter colours, while other areas such as the doors and windows were often painted or stained a darker hue.

1971 archival photo capturing a common historic colour scheme of townhouses, where ornamental moulding details are picked out in white and contrasted against pastels, with painted timber windows in a different tint.

Right: *Mural artwork covering the entire facade dominated by oxide red on an ultramarine blue background, 66 Spottiswoode Park Road.*
Far right: *Historic colour schemes of ochre limewash followed by white and grey camouflage are revealed after latter-day incompatible paint has been stripped, at Victoria Concert Hall.*

However, the recent discovery of the original painting scheme of a 1890s townhouse during renovation works showed that there were more variations and types of paintwork than what most assumed. The columns and innerleaf facade of the five-foot way are painted a rust-red hue, while the upper storey facade featured a bold mural of rust-brown and ultramarine blue patterns above framed decorative vignettes.

PUBLIC AND GOVERNMENT BUILDINGS

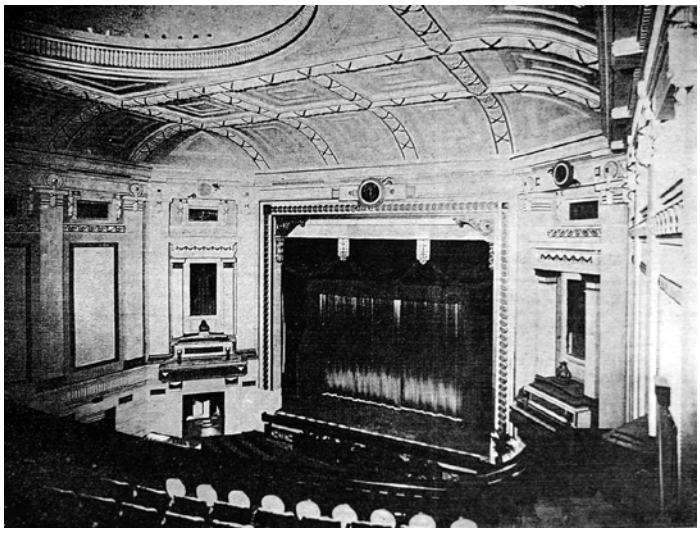
Prewar government buildings were mainly in yellow or **ochre** colour. Many prominent public and government buildings were painted in a **camouflage scheme** of white, grey and brown during World War II. In the postwar years, a colour scheme of white walls with 'Brunswick green' timber fenestration was commonly adopted for these buildings.

Though not the original colour scheme of the historic mansion it occupies, the bright red paint scheme adopted by the bakery became highly imageable.

COMMERCIAL AND INTERIOR TRENDS

Paint schemes are also invariably associated with personal preferences, function and cost. For example, the Red House Bakery, at both its old Victoria Street and later East Coast Road locations, had its entire facade painted red as a form of **image branding**.

A 1936 *Morning Tribune* article titled 'New Colours: Suggestions in Colour Schemes for Decorating New Interiors' suggested that popular taste on the domestic front was seeing a 'Georgian vogue' at the time – it had 'emerged from the beige decade and the all-white stuff of the 1920s though it is too charming a scheme to be entirely given up. Now the all-white rooms have had bright colour added and all the beige rooms have been re-done.'



Left: *Interior photograph of the Capitol Theatre when it just opened, showing tonal differences and highlights, with reflective gold on the mouldings appearing as dark lines.* ***Right:*** *Residual paintwork of historic art deco colour scheme found on the beams and columns of the former Capitol Theatre restaurant.*

Places of entertainment are also expected to be colourful to attract patrons. The press release on the opening of **Capitol Theatre** in 1930, carried in various newspapers, provided detailed information on the decorative paintworks supplied and executed through a local agent by the US-based Sherwin-Williams Paint Co., a first in Singapore. Unlike traditional distempers, 'all the paints can, even when dirtied with ink, be washed clean again.'

The Journal of Institute of Architects of Malaya observed in a feature write-up that the interior surfaces at the Capitol were painted with a cream coloured flat-tone or matt finish paint. Public areas such as the entrance corridor, foyers and restaurant, were rendered a multicoloured effect obtained by stippling one or more colours on a ground tint. The vaulted ceiling and dome were finished with 'a texture which is very attractive in artificial light, and kept mainly in silver-grey with green stippled panels on a rough texture, and mouldings have been picked up in gold, together giving a very pleasing effect.'

In 1931, *Malaya Tribune* reported on the redecoration scheme of the **Pavilion Theatre** – 'walls are in three colours, one superimposed over another, giving a soft and cheerful effect quite the opposite of the monotonous glare of one-colour walls… The three colours used throughout are green, buff, and a lavender grey - the combination giving the walls a tapestry effect which fits the mood of the theatre as nothing else could have been done.'

PAINTED MURALS AND RELIEFS

Prewar painted artworks commonly found on historic townhouses, Chinese temples, Hindu temples and churches are often frescoes. **Fresco** is a mural painting technique where pigments are applied directly on freshly rendered, moist **lime plaster**. The coloured pigments become an integral part of the plaster finish as it cures.

Many building traditions have provisions for **cyclical renewals**, and this extends especially to non-structural ornamentation such as murals or sculptures. For example, the consecration ceremony to re-sanctify a Hindu temple takes place once every 12 years, during which it is typically refreshed with repairs and repainting works. It is worth bearing in mind, though, that even in the past, most cycles had maintenance repairs rather than extensive renewal, and artworks that were highly significant or elements in good working condition were **continuously mended and retained**, with every effort put in to maximise their lifespan and reduce wastage.

The vastly transformed building economics today, where replacement is often more cost-efficient than repair, has driven the tendency for excessive and frequent renewals in the recent decades. With changes in mainstream paint use over time, most painted artwork in Hindu and Chinese temples in Singapore, both new creations and repainting of historic ones, are now executed in modern synthetic paints rather than the traditional fresco technique with mineral pigments.

When applied on early historic building surfaces, however, this has affected their breathability, aggravating rising damp problems and causing paint, plaster and even brick substrate deterioration over time.

Nonetheless, with growing heritage awareness, it has been increasingly common to recognise the historic and artistic value of old artworks even if they may be deteriorated, and sensitively conserve those assessed to be of significance.

Modern synthetic paints used on relief sculptures and dome.

Fresco painting using mineral pigments.

Conservation considerations

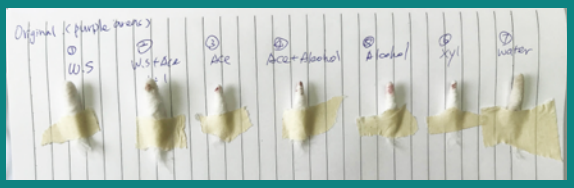
Given its fragile nature, sensitivity of material, and artistic skills required, preserving mural artwork is never simple and straightforward. Other than frescoes, this applies also to other types of painted murals on buildings, including early modern artwork using synthetic paints.

The condition, authenticity, artistic and historic value of the existing artwork should first undergo detailed **conservation assessment** by a qualified conservator or mural expert. If verified to be of significant value, all existing paintwork should be retained to the maximum.

Research should be carried out on its iconography and history, including studies of old photos, archival documents and similar artwork of the same period. Sometimes, artworks are badly deteriorated or have missing panels or sections. Often, however, there are insufficient past records or historic reference of the original to inform about the missing parts. Detailed **documentation**, including **paint analysis**, of the existing historic artwork should be carried out prior to any conservation works.

Expert recommendation should be sought regarding the most suitable **conservation approach**, and provide technical advice on **compatible conservation materials** such as paint, cleaning agent or protective coating, based on paint analysis results.

Common issues observed on painted murals of conserved townhouses resulting in loss of heritage character and artistic value:
Top: ***Overpainting and loss of visual coherence***
Above: ***Inappropriate restoration - repainting of historic artwork with lesser skill. Details tend to be omitted and colour scheme changed due to lack of proper documentation, research and paint studies prior to restoration.***



Trials by the paint conservator to test the suitability of different cleaning agents for restoring a mural artwork.

Following are a few possible approaches:

- RETAIN AS-IS: Where authenticity is prioritised, and the 'as-found' state of the mural is embraced, the **residual artwork** could be retained, stabilised and protected as it is, without attempting to fill in or recreate lost sections.
- RETAIN WITH SENSITIVE TOUCH-UP: Where authenticity is prioritised alongside visual coherence and heritage presentation, apart from conserving the existing artwork, the Italian-developed technique of **trattegio** could be applied, where missing parts are filled in using repetitive brushstrokes, referencing historic documentation to closely match the original. The new infill parts remain distinguishable, but only upon close scrutiny. Where original details are unknown due to lack of records, these are not recreated from speculation; rather, matching neutral colours are applied, providing just enough visual cues for a coherent reading of the original artwork.
- REPAINT: An artisan team may be engaged for total **recreation** of the artwork as part of traditional cyclical renewal. Often, given the difference in current paint materials, colours, painting styles and skills, the original is mainly matched only in composition and iconographic intent. This approach would also result in total loss or overpainting of the original artwork, and would not be suitable for murals of high artistic or historic value.

Painted ornamental border uncovered on an interior wall during restoration – such residual artwork could be retained and restored as is to give heritage character to a space.

Historic mural art that was gently cleaned, stabilised and protected, with missing sections filled in using the trattegio technique, to retain its historic character. The artworks were uncovered after paint stripping during the adaptive reuse restoration of Lhong 1919, Bangkok, Thailand.

Conservator studios or artisan workshops with the requisite skills, knowledge and experience should always be engaged to undertake the mural artwork restoration. Apart from the paintwork, other conservation works that are usually required include substrate repair (e.g., infill of minor cracks), controlled stripping of inappropriate or overpainted coatings, gentle cleaning, surface consolidation, and application of protective coating.

For interior mural artworks, it is important to maintain a suitable **indoor environment**. Constant high humidity and warm temperature may lead to mould infestation.

Common Deterioration, Causes and Diagnostics

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

Refer also to *Volume 3 Facades*, Chapter 2 Plasterwork, 'Common Deterioration'.

VISUAL AND TACTILE SURVEY

Visual and tactile assessment of paint coats on plaster surfaces should take note of the following defects and their likely causes:

- **Fading and discolouration** may result from a number of factors, such as environmental conditions including pH levels and light exposure, and oxidation. Fading often happens to coatings with pigments that are not light-fast, such as those from plant sources. It may also arise from inappropriate maintenance practice using unsuitable cleaning agents or coating material.
- **Biological growth** such as moss, algae, mould and plants indicates an underlying and persistent moisture problem.
- **Staining** may be due to accumulated dirt, animal droppings, back splash, environmental soot, rust stains, etc.

Left: *Weathered and faded mural artwork on a historic townhouse facade.*
Right: *Downpipe leakage left unaddressed resulting in staining, algae and plant growth.*

- **Chalking** is mainly due to the photochemical breakdown of the binder in paints, largely due to exposure ultraviolet rays, resulting in a powdery surface.
- **Efflorescence**, or **salt attack**, is indicative of the presence of moisture within the substrate which carries soluble salts to the surface where they re-crystallise. This creates a whitish appearance, and repeated cycles of leaching of the soluble salts can build up to form unsightly surface deposits.
- **Bubbling, blistering and peeling** or delamination of film-forming paints are the result of the loss of adhesion between coating layers or between coating and substrate. These issues are typically caused by improper surface substrate preparation, incompatibility between coating layers and trapped moisture or water vapour.
- **Inappropriate paintwork** includes use of unsuitable paint types during maintenance or repairs, thick multiple layers of overpainting leading to obscured moulding profile, inappropriate colour scheme, etc.
- **Hollow plaster** may be detected by tapping the plastered surface with a rod and listening for hollow-sounding taps.

Top: *Efflorescence on historic painted mural.* ***Above:*** *Blistering and peeling of interior paintwork, in addition to plaster failure, due to long-term water ingress from roof leakage.*

Left, middle: *Cracks, delamination, bubbling and sagging of film-forming emulsion paint inappropriately applied on historic walls.* ***Right:*** *Following paint removal, hollow-sounding plaster is marked up according to tactile survey of facade.*

Refer to *Chapter 1 Introduction, 'Paint Analysis and Diagnostics'* for details on main diagnostic and paint analysis methods.

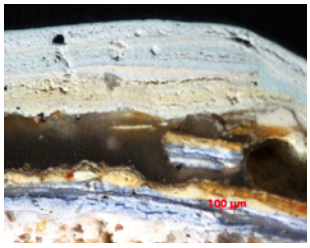
Refer also to *Volume 3 Facades,* Chapter 2 Plasterwork, 'Diagnostics'.

NON-DESTRUCTIVE TESTS, SAMPLING AND LABORATORY ANALYSIS

Apart from archival research and visual/tactile survey, further investigations may be carried out using non-destructive test equipment or laboratory analysis of extracted samples for **condition assessment**, and **material/colour identification**.

Condition assessment:

- **Infrared Thermography** to detect plaster hollowness or presence of trapped moisture.
- **Relative moisture content** checks could be carried out using two-pin moisture meter (surface), capacitance-based meter (subsurface) and microwave moisture tomography (various depths).
- **Adhesion tests** to assess how well-bonded the coating is to its substrate include the cross-cut or cross-hatch tests, as well as the use of a portable pull-off adhesion tester.



Microscopic examination of thin-section paint and plaster sample for material and colour identification of substrate and coating layers accumulated through history.

Material/colour identification:

- **Paint seriation** could include basic in situ methods such as controlled paint stripping to create a paint ladder. For more accurate results, a sample that includes all paint layers and the substrate needs to be extracted for **thin-section microscopic examination**, where each coating layer can be closely studied for its physical characteristics such as colour, thickness, etc.
- **Chemical solvent tests** are used to detect the paint binder material, including diluted inorganic acid (lime and cement), acetone (organic synthetic resin) and alkali (oils).
- **Chemical instrumental examination** may also be considered for high-precision results, including FTIR (Fourier Transform Infrared Spectroscopy - organic/polymeric substance), XRF (X-ray Fluorescence Spectroscopy – inorganic elements e.g., titanium, lead, zinc, silicon, etc.), SEM and EDX (Scanning Electron Microscope and Energy Dispersive X-ray Spectroscopy – microscopic paint study on concentration and distribution of chemical constituents).

Conservation and Intervention

Refer also to *Chapter 1 Introduction, 'General Notes on Conservation and Intervention'*, as well as *'Painted Murals and Reliefs'* in this chapter for conservation approaches to painted artwork of historic and/or artistic significance.

Advice from material and conservation experts should be sought in the selection of appropriate conservation approach, methods and materials, based on paint analysis results where available.

CONTROLLED PAINT STRIPPING

The controlled removal of inappropriate or unsound/degraded coatings may be carried out when the conservation scope involves restoration of overpainted historic paintwork, repainting, and also restoration of originally fairfaced finishes. The removal method and material used should be carefully selected to minimise damage to the underlying or adjacent historic finish or substrate. Corrosive chemical paint stripper with toxic and highly reactive chemical should be avoided; instead, biodegradable, pH-neutral paint stripper is recommended.

The coatings may be removed down to the historic layer to be retained, or removed completely in the case of repainting works and fairface restoration. Any unsound parts of the historic coating will also have to be removed, to be filled in later with touch-up repair.

Above: *Inappropriate scraping removal of coating layers caused damage to historic paint finish with original stencilled patterns and Chinese characters.*
Right: *Manual paint scraping, carefully done to avoid damage to underlying layers.*

Chemical paint stripper is applied on the painted plaster moulding, covered with shrink wrap and left to act on the paint coats, before removal by scraping.



Controlled paint-stripping should only be carried out by skilled and experienced workers under supervision. Possible methods are as follow.

- **Manual paint scraping**
- **Low-pressure water jet**
- **Low-pressure rotary jet-blasting** for paint removal from textured historic finishes such as Shanghai plaster.
- **Chemically compatible paint strippers** may be applied and left on to break down the coating, before removal by scraping.

Gentle cleaning and micro-injection to infill cracks during a mural artwork conservation process.



CLEANING AND CONSOLIDATION

The first step in conserving existing historic paintwork or mural art on plasterwork is usually controlled and gentle **cleaning**. High-pressure cleaning and use of incompatible cleaning materials or corrosive chemicals should be avoided.

Surface consolidation and repairs for the existing artwork may also be necessary to arrest deterioration and reinstate surface soundness. If touch-up is needed, it should be carried out by qualified and skilled conservators/artisans using appropriate material and method.

Application of reversible **protective coating** over the cleaned and restored paintwork or mural art will help prolong its life, especially if it is located on the exterior, or at high-traffic reachable areas. Such protective coating should resist UV-rays which cause photodegradation, and prevent water ingress and water damage, while not altering the original appearance – it should not be tinted or high-gloss, for example. Protective coatings may also be applied during conservation maintenance as a form of **preventive conservation**.

To further protect historic coatings with pigments that are not light-fast, sensitively designed shelters may be considered to reduce or eliminate exposure to the ultraviolet radiation of sunlight. Transparent screens are also sometimes installed for highly valued artwork to prevent casual touching.

REPAINTING

For simple paintwork, repainting may be carried out if there is extensive paint, plaster or masonry substrate deterioration. Any damage or root problems (such as roof leakage or rising damp) should be addressed and resolved prior to repainting works.

Paint selection: The repainting colour scheme should draw reference from historic colour schemes based on paint seriation and research findings. The selection of replacement paint material should take into consideration the retained or newly applied substrate, retained historic paint material, and exposure environment.

Most mineral paints sold on the Singapore market are formulated in accordance to DIN 18363:2016-09 (Painting and coating work). Some are also manufactured to BS EN 1062-1:2004 (Paints and varnishes).

Particularly for prewar historic buildings, a **vapour permeable coating** is usually recommended for plastered surfaces, to facilitate evaporation of vapour from within the plaster layer and prevent moisture accumulation.

Examples used for conservation include modern limewash paint, **mineral silicate** paint and silicone paint. However, silicate paints need to be applied directly on the plaster substrate, and thus require complete removal of all past coatings. In such cases, paint analysis and documentation should be carried out before paint removal and loss of historic coatings.

The breathability of a paint layer is measured by its 'Sd value', which quantifies a material's ability to allow the passage of water vapour, tested in accordance with ISO 7783:2018 (Paints and varnishes - Determination of water-vapour transmission properties). Better breathability is indicated by lower Sd value, measured in meters (referring to the equivalent distance through which water vapour travels through air). For example, limewash has a value of 0.02m, in contrast with 0.5m of a current-day typical paint.

Exterior and interior repainting using mineral silicate paint, which requires thorough removal of past coatings.

Substrate preparation: Where found to be historic and of relatively sound condition, the plaster substrate should be retained, especially for moulded stuccowork of good craftsmanship. Only parts that are defective, and where the underlying masonry needs to be repaired, may be removed and patching repair done using plaster compatible to the historic. Particular care should be taken to use lime-based material for historic lime plaster.

An additional skim coat may sometimes be applied if the historic substrate is rough or uneven, mainly for aesthetic reasons, and should similarly be carried out using compatible plaster.

Application and quality checks (QC): In most cases, primer application on the prepared substrate is needed to even out tonality difference and enhance the bonding of new paintwork. It is recommended to carry out quality check tests (QC) during and after the application of new paintwork. Before repainting, the substrate surface should be sufficiently dry - advice from the paint supplier should be sought for the extent of dryness required, as well as curing/bonding time for the particular paint type. **Moisture test** could be carried out to determine the extent of dryness/dampness. After adequate curing/bonding of the new paintwork, a cross-cut or pull-off **adhesion test** may be considered to assess its bonding with the plaster beneath.

Refer to *Chapter 1 Introduction, 'Paint Analysis and Diagnostics'* for more details on the respective tests for moisture and adhesion.

3 ON TIMBER AND METAL

Overview

Refer to *Chapter 1 Introduction, 'Overview', 'Common Terms'* and *'Common Historic Architectural Coatings'* for more information on basic concepts and common types of paint historically used on timber and metal in the local context.

TIMBER

Common timber architectural elements in historic buildings include roof systems (trusses, rafters, purlins, batons), floor systems (beams, joists and boards), fenestrations (door/window frames and leaves), walls (sidings, partitions and panelling). The cellulose found in timber, being an organic material, is prone to attack by insects (such as termites or wood-boring beetles) or fungi.

Internal partitions, ceiling or wall panelling, and especially floor elements were often only oiled/waxed, varnished or lacquered, the visual warmth and tactility of natural woodgrain being the preferred finish for highly visible and well-used interior areas. The frequent upkeep and reapplication of these protective coatings, such as **linseed oil**, **tung oil** (also known as China wood oil), **shellac**, **beeswax**, **microcrystalline wax** and **varnishes**, were part and parcel of common maintenance practices in the past.

Left: *Many government buildings had their fenestrations painted in 'Brunswick green' in the postwar years, including the Victoria School. The second storey french windows, being more exposed to the elements, were more faded and discoloured than the sheltered ground floor doors.* ***Right:*** *Historic interior with timber finishes that are just dark stained to retain the warmth and tactility of natural wood grain, Tanjong Pagar Railway Station.*

Left: *Painted roof trusses, St George's Church.* ***Right:*** *Carved timber structures finished in daqi and decorated with oil-based gilding artwork, Wak Hai Cheng Bio.*

Fenestrations, roof elements, exterior sidings and structures, being subjected to more stresses including exposure to elements, and which may be more challenging to replace or less accessible, were commonly coated with **oil-based paint** or **lacquer** for more lasting added protection. In the case of opaque paints, undercoats may be applied, serving to even out substrate surfaces and provide termite resistance, etc. **Daqi**, or Chinese lacquer paint, is a hard, opaque finish traditionally applied on timber structures and elements in Chinese houses and temples.

Timber may also feature painted ornamentation and murals – elaborate examples can still be seen at traditional Chinese temples and are likely to have adorned many church interiors.

Residual historic painted artwork on the timber ceiling of a former convent chapel – though retained, the delicate silhouette of the historic mural artwork is marred by the insensitively executed current day paintwork.

'BLACK AND WHITE' BUNGALOWS

1931 photo of a bungalow built for Harbour Board officials, in the distinct 'black and white' half-timbered construction.

Early government-designed quarters built in clusters all over the colony from the late 19th century to before WWII were colloquially known as 'black and white' bungalows since at least the 1920s. These were mostly raised or two-storeyed **half-timbered** structures – the upper level was constructed of exposed timber structural frame with masonry infill walls that were plastered and painted. The exposed timber structural frame was coated in black tar paint, also known as bituminous paint or creosote paint, for its preservative, pesticidal and waterproofing properties. Together with the white limewashed infill walls, the stark colour scheme gave rise to the name 'black and white' bungalows.

While the 'black and whites' are numerous, not all colonial-era houses featured such construction or colour scheme. In fact, not even all government-designed bungalows were in black and white. However, it has become a trend to indiscriminately apply this colour scheme for a thematic 'look', often on historic structures that are not even half-timbered, obscuring their true heritage character. As such, it is important to carry out paint analysis to determine the true historic colour scheme to be reinstated.

TIMBER GILDING

Oil-based gold gilding during the 2010s restoration of the temple Wak Hai Cheng Bio.

There are two types of gilding, water-based and oil-based gilding. Water-based gilding, primarily used for building interiors, is not commonly found on Singapore's buildings due to the more humid climatic conditions. The constantly elevated ambient moisture content can result in gilt failure and loss.

The more common type of gilding found in buildings in Singapore is the **oil-based** type, typically found in Chinese temples on timber.

The timber substrate has to be properly prepared to ensure all the grains and pores are covered with fine timber putty. Once the putty is dried, it is smoothened by fine sanding before the application of a thin layer of an oil-based size that could be prepared using tung oil, boiled linseed oil or a mixture of tung oil and Chinese lacquer. The oil-based size is allowed to dry to the point of almost losing its stickiness. The gold leaf is then applied using a gilder's tip brush. In the case of 24-karat gold leaves, it is not necessary to finish with a clear sealer or protective tung oil coating. Lower-karat leaves will generally need a protective coating to prevent tarnishing or discolouration.

Left: *Tinted postcard showing imported cast-iron ornamental fencing at the Istana depicted as red - likely red lead paint.* ***Right:*** *Iron structures assembled from imported prefabricated parts were often shop-primed in the foundry and finished with coatings later, black lead paint being a common colour.*

Historic pressed metal ceilings are usually painted in the local context.

METAL

Historically, most painted architectural metals were ferrous elements; brass, bronze and copper items were often not applied with coatings, though bronze items may be waxed. Pressed metal ceilings in steel, tin or zinc were also often painted. In the colonial period most iron or steel architectural elements were imported and would have arrived already shop-primed – coated with a primer (often red lead paint tinted with iron oxide pigments) in the foundry – for protection against rusting.

Entire structures such as bridges or markets may be assembled from prefabricated cast-iron units ordered off catalogues, while steel I-beams and other modular units were similarly imported for erecting large-span military or industrial buildings, and so on. Other painted metal elements commonly seen on historic buildings include gates and fencing, fenestration, staircases, porches or courtyard feature columns, rainwater goods, roof ridge ornaments, and so on. Common finishing colours in the prewar period appear to be red, black and green, as well as white or grey - especially for rainwater downpipes to match wall finishes.

Common Deterioration, Causes and Diagnostics

VISUAL AND TACTILE SURVEY

Visual and tactile assessment of paint coats on timber and metal surfaces should take note of the following defects and their likely causes, many of which are similar to those of paint on plaster:

- **Cracking, flaking and loss** of oil-based paint over time as the coating ages, becomes more brittle, and less able to withstand thermal movements, or contraction and expansion, of the substrate.
- **Bubbling, blistering and peeling** or delamination of film-forming paints are the result of the loss of adhesion between coating layers or between coating and substrate. Apart from the natural ageing deterioration of the paint, these issues are also typically caused by improper surface substrate preparation, incompatibility between coating layers and trapped moisture or water vapour. These are also common surface defects that indicate substrate deterioration issues, such as timber weathering or wet rot, and corroded or tarnished metal.

Refer to *Chapter 1 Introduction, 'Maintenance and Common Issues'*, for more information on the key principles and systemic problems related to deterioration and maintenance, and section on *'Paint Analysis and Diagnostics'* for details on main diagnostic and paint analysis methods.

Refer also to *Volume 5 Doors and Windows*, Chapter 2 Timber and Chapter 3 Metal, the respective sections on 'Common Deterioration, Causes and Diagnostics' for more information on defect analysis of the respective substrate.

Right: *Cracking, flaking and loss of oil paint from natural ageing and weathering.*
Far right: *Delaminating paint of a metal sheet exterior cladding on a timber door.*

- **Fading and discolouration** may result from a number of factors, such as environmental conditions including pH levels, pollution and light exposure, and oxidation. An example is the darkening of lead paints in the presence of sulphide gases. Oxidation of timber and metal paints over time may also lead to chemical changes that results in **yellowing**. Such chemical changes may also arise from inappropriate maintenance practice using unsuitable cleaning agents or coating material.
- **Biological growth** such as moss, algae, mould and plants indicates an underlying and persistent moisture problem.
- **Staining** may be due to rust stains, accumulated dirt, biological growth, animal droppings, back splash, environmental soot, etc.
- **Chalking** is mainly due to the photochemical breakdown of the binder in paints, largely due to exposure to ultraviolet rays, resulting in a powdery surface.
- **Wrinkling** is the deformation of the paint film due to poor application technique, typically a result of coating layers applied too thickly, or coatings applied before the previous coat has dried.
- **Inappropriate paintwork** included use of unsuitable paint types during maintenance or repairs, thick multiple layers of overpainting leading to obscured moulding profile, inappropriate colour scheme, etc.

Painted timber ceiling of a shophouse five-foot way – only planks on the left side are mould-infested, indicating a persistent moisture problem.

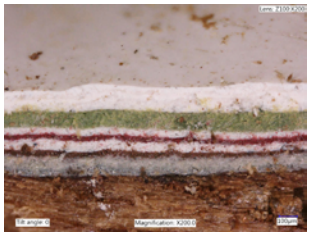
Left: *Fading and rust staining on a painted H-column.* ***Middle:*** *Wrinkling of paint film due to coating that is overly thick or applied before the undercoat has dried.* ***Right:*** *Overpainted rainwater downpipe, obscuring the ornamental profile and any festering defects.*

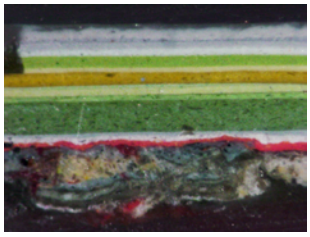
NON-DESTRUCTIVE TESTS, SAMPLING AND LABORATORY ANALYSIS

Apart from archival research and visual/tactile survey, further investigations may be carried out using non-destructive test equipment or laboratory analysis of extracted samples for **condition assessment** and **material/colour identification.**

Condition assessment:

- **Infrared Thermography** to detect presence of trapped moisture.
- **Relative moisture content** checks could be carried out using two-pin moisture meter (surface), capacitance-based meter (subsurface) and microwave moisture tomography (various depths).
- **Adhesion tests** to assess how well-bonded the coating is to its substrate include the cross-cut or cross-hatch tests, as well as the use of a portable pull-off adhesion tester.





*Thin-section paint seriation microscopic study of **(from top)** painted timber and painted cast-iron downpipe.*

Material/colour identification:

- **Paint seriation** could include basic in situ methods such as controlled paint stripping to create a paint ladder. For more accurate results, a sample that includes all paint layers and the substrate needs to be extracted for **thin-section microscopic examination**, where each coating layer can be closely studied for its physical characteristics such as colour, thickness, etc.
- **Chemical solvent tests** are used to detect the paint binder material, including diluted inorganic acid (lime and cement), acetone (organic synthetic resin) and alkali (oils).
- **Chemical instrumental examination** may also be considered for high-precision results, including FTIR (Fourier Transform Infrared Spectroscopy - organic/polymeric substance), XRF (X-ray Fluorescence Spectroscopy – inorganic elements, e.g. titanium, lead, zinc, silicon, etc.), SEM and EDX (Scanning Electron Microscope and Energy Dispersive X-ray Spectroscopy) – microscopic paint study on concentration and distribution of chemical constituents.

Conservation and Intervention

Refer to *Chapter 1 Introduction, 'General Notes on Conservation and Intervention'*, for more discussion on conserving or reinstating paintwork.

Refer also to *Volume 5 Doors and Windows*, Chapter 2 Timber and Chapter 3 Metal, the respective sections on 'Conservation, Intervention and Maintenance' for more information on repairing timber and metal substrates.

Advice from material and conservation experts should be sought in the selection of appropriate conservation approach, methods and materials, based on paint analysis results where available.

PAINT STRIPPING

The existing defective paint layer needs to be first removed using manual scraping, followed by the use of biodegradable, pH-neutral paint stripper and wire-brushing for metal, or sanding for timber. Other specialised paint removal methods available in the market include laser cleaning, infrared heating, dry ice and low-pressure rotary jet-blasting. However, these need to be tested via trials for their suitability.

CLEANING AND CONSOLIDATION

Conserving historic paintwork or ornamental artwork on timber or metal begins with controlled and gentle **cleaning**. Avoid high-pressure cleaning and use of incompatible materials or corrosive chemicals.

Surface consolidation and repairs for the existing artwork may also be necessary to arrest deterioration and reinstate surface soundness. If touch-up is needed, it should be carried out by qualified and skilled conservators/artisans using appropriate material and method.

Application of reversible **protective coating** over the cleaned and restored paintwork or mural art will help prolong its life, especially if it is located on the exterior, or at high-traffic reachable areas. Such protective coating should resist UV rays which cause photodegradation, and prevent water ingress and water damage, while not altering the original appearance – it should not be tinted or high-gloss, for example. Protective coatings may also be applied during conservation maintenance as a form of **preventive conservation**.

FIRE PROTECTION

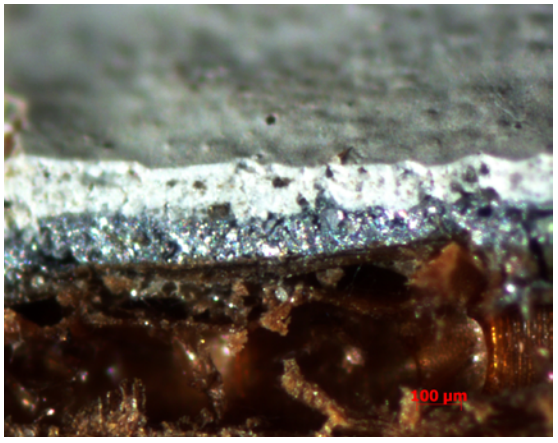
The application of **intumescent paints**, or fire-protection paints, is primarily for metal fixtures according to building codes and specifications. These paints react to the presence of high heat and undergo a chemical and/or physical change to form a protective layer. They come in limited colours but may serve as a finishing coating. Other than metal, they can also be applied to timber and concrete.

REPAINTING: TIMBER

Substrate preparation: Prior to the application of new coatings, any defects on the timberwork should be repaired. Timber putty is typically used for minor patching and sanded down to smoothen out uneven surfaces if opaque paints are to be applied subsequently.

Preservative treatment, available as an applied liquid product, is recommended for the repaired timberwork to provide additional protection from termite and fungal attack. Moisture check should be made on the timber before repainting as excessive moisture content at this point may result in timber shrinkage later on, or cause inadequate curing of new paint.

Paint application: The typical types of paint for timber today include alkyd- or oil-based paint, polyurethane- or a blend of polyurethane and acrylic-based paint. A layer of primer is usually applied to facilitate adhesion of subsequent coatings. Aluminium primer with good sealing property is one of the popular types used for wood, due to its excellent ability to prevent resinous excretion from timber.



Left: *Historic timber staircase with existing defective paint stripped, and patched with timber putty as part of substrate preparation for new paintwork.* ***Right:*** *Timber paint seriation microscopic image cropped to show silver-coloured aluminium primer as the first layer applied on the timber substrate.*

REPAINTING: METAL (STEEL)

Substrate preparation: Corrosion repair and treatment of the affected steelwork needs to be carried out prior to the application of new coatings. Surface rust removal should attain SA 2.5 sandblasting grade. In order to develop a good corrosion resistance system for the steelwork, the surface could be treated with the sequential layers below.

1. **Anti-corrosion primer:** zinc-rich primer which works by creating an electrochemical sacrificial layer to protect the steel substrate.
2. **Intermediate layer:** Micaceous iron-oxide coating which works by forming a barrier with overlapping plates/flakes to prevent infiltration of corrosion-promoting factors such as oxygen and moisture.
3. **Finishing layer:** The final protective finish layer which could be polyurethane, epoxy or other material to form a physical barrier.

Alternatively, if the ideal surface preparation to achieve SA 2.5 grade cannot be reached, consideration could be given to the use of **rust convertor** and **organic resin primer**. Recommendations from the supplier should be sought for their application and suitability.

Quality check (QC) is recommended during and after the application of new paintwork. When the new paint coat has cured sufficiently, a cross-cut/cross-hatch adhesion test or pull-off adhesion test could be conducted to assess if the coating is adequately bonded with the substrate beneath.

Cast-iron balustrade stripped to SA 2.5 grade in preparation for repainting – the removal of multiple paint coats reveals the fine profile and details.

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ASTM (ASTM International, founded as American Society for Testing and Materials)
SS (Singapore Standards)

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