CONSERVATION TECHNICAL HANDBOOK

A GUIDE FOR BEST PRACTICES

Volume 3 | Facades

ICOMOS SINGAPORE

URBAN REDEVELOPMENT AUTHORITY

Conservation Technical Handbook
Volume 3 | Facades

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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 handbook. Through judicious planning, Singapore has conserved more than 7,000 buildings and structures since 1989. They cover different building types, architectural styles, scales and genres. They are our precious legacy that must be protected for current and future generations of Singaporeans.

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

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

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

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

About This Series

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

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

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

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

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

Dr Kevin Y.L. Tan
President
ICOMOS Singapore

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Look out for margin notes such as this one, which will give you further advice or link you to other parts of the book.

What do the icons mean?

- General tips and advice
- Concepts learnt in other chapters or volumes
- Worksheets are available
- External references
- Further reading and topical notes

About This Volume

Volume 3: Facades is the third book in a series of eight **Conservation Technical Handbooks**, and highlights key challenges and principles for conserving materials commonly used on facades of historic buildings in Singapore.

Chapter 1 Introduction examines the role and development of the facade as an architectural feature in historic buildings. It also outlines problems common to the conservation of all types of facades, including points to note about their long-term maintenance.

Chapters 2 to 9 are organised according to materials so that you can quickly refer to the relevant sections as and when you encounter a particular material.

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

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

Common Deterioration: Facades serve first and foremost as the external barrier of a building. This section explains the common types of facade defects and their causes, especially due to constant exposure to weather, and other issues associated with facades that building owners may face when conserving or repairing their building.

Diagnostics: This section provides methods for inspecting and diagnosing issues in the facade material. Where possible, both simple, do-it-yourself methods of diagnosis, as well as methods that require specialists to carry out are provided.

Conservation and Intervention: This section outlines steps that are commonly taken to address causes of deterioration, as well as restore and protect dilapidated historic materials.

Maintenance: This section highlights particular characteristics of the material or element that may affect how it performs, and recommendations for long-term care and upkeep.

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

Do look out also for **box stories** and **helpful tips** in the margins for more in-depth discussion of the material or element at hand.

1 INTRODUCTION

Overview

Facades are high on the priority list in conservation consideration, being the most recognisable aspect of built heritage presentation, and the public face of the building. They give character, scale and historical layer to a public space or urban streetscape. Facades serve to signal the building's function and the owner's or occupant's social status, wealth, taste and branding (for businesses).

Windows and doors, essential components of facades, will be covered in Volume 5. This volume will focus instead on the finishing materials and elements of the main envelope.

The existing range of heritage buildings in Singapore, dating from the early colonial period to postwar years, are predominantly finished in plaster render and paint, with variations such as moulded ornaments and textured plaster. Fairface masonry facades are mostly in brickwork rather than natural stone. From the interwar years onwards, Shanghai Plaster gained popularity. As building technology evolved, precast concrete elements such as ornaments, vent blocks and sunshading fins became available for installing on facades. Tile finishing on facades only took off in a major way from the postwar years, enabled by mass production and used even on high-rise buildings up to the 1980s.
The postwar years also saw the evolution of facade cladding in a range of materials, either as 'tiles' laid on a substrate wall or self-supporting units hung on structural frames.

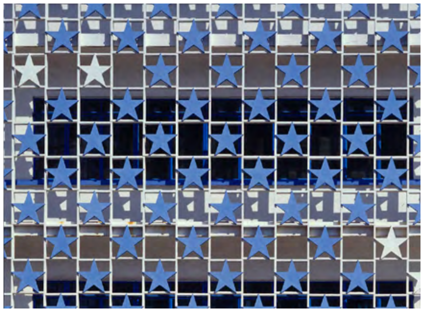
Following page: General Photos of facades of different materials found in Singapore.

KOON SENG ROAD SHOPHOUSE

FORMER ASIA INSURANCE BUILDING

FORMER WING ON LIFE BUILDING

CHURCH OF THE BLESSED SACRAMENT



LEA HIN CO. METAL FACTORY

MALABAR MOSQUE

SERANGOON FIRE STATION

PETAIN ROAD TERRACE HOUSES

STAMFORD HOUSE

CLIFFORD PIER

BUKIT PASOH SHOPHOUSES

FUTURA APARTMENT

Back to previous view

Notes on Facade Conservation Works

Brick substrate exposed after removal of incompatible plaster render at Stamford House.

SUBSTRATES

Facade finishes like plaster render, ceramic or stone tiles are applied on backing substrates such as brick or cement hollow block walls, or metal mesh. Though they may be concealed, substrate deterioration or defects, for example cracks or disintegration, have to be addressed as the first step in restoring facade finishes. If left untreated, they may worsen and affect the restored finishes, causing more serious problems down the road.

TRIALS AND MOCK-UPS

Facades are the most visible aspect of heritage buildings. Any repair and restoration methods should be put through progressive trials and tests for material compatibility, aesthetics and skill, in an inconspicuous corner or as an off-site mock-up, before being applied on the entire facade.

*Plaster rendered on metal mesh substrate **(above)** for lightweight parapet wall **(top)** at the former Traffic Police Headquarters.*

Mock-up for ornamental plaster mouldings at Victoria Concert Hall.

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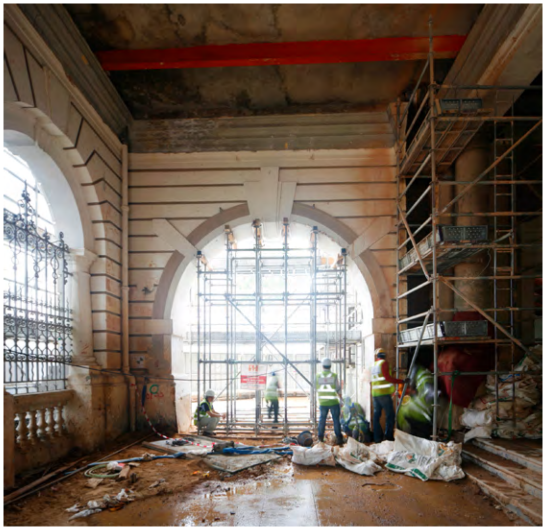
PROTECTION

During major conservation works, or when scaffolding or props are erected against facades, conservation specialists should be consulted on which are the key features and vulnerable areas to be protected against accidental impact, such as protruding mouldings or delicate filigree. Depending on the risks, these could be protected in situ, for example using bracing frames, high-density foam wrapping, bubble wrap, or by fixing with nets to catch dislodged parts. Some components such as windows, doors or lamps may also be dismantled for safe storage or off-site restoration, and reinstated after the completion of heavy works.

An archway with bracing frames where contact points are padded with timber ***(right)****, and column base protected with timber board and concrete angles* ***(below)*** *against accidental impact during construction, at Victoria Concert Hall.*



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SCAFFOLDING AND PROPPING

Scaffolding, erected for high-level inspections or works, is frequently located along facades. Structural propping may also be set up to support facades during major conservation works where interventions affect interior structures. Utmost care should be taken when designing scaffolds or propping, to minimise direct anchorage or tiebacks on the facades, and to avoid impacting key features. Tiebacks or clamps should not come into direct contact with the building fabric, and should be padded with foam spacers.

Above: *Temporary structural propping for facades.* ***Left:*** *Scaffolding and props erected without impacting facade fabric and finishes – anchorage achieved by padded clamping and utilising existing openings.*

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Notes on Facade Maintenance

Due to the tropical climate of Singapore, exposed building fabric is subject to particularly stressful conditions, such as frequent rain, thunderstorms, solar heat and high humidity. Under these conditions, facades, and also roofs, are prone to quick organic growth (both vegetation and moss), erosion and disintegration, salt attack, stains, and damage from impact. This can also be caused or aggravated by defects in related building parts, such as broken gutters, cracked roof tiles and misaligned windows.

INSPECTIONS

A **general inspection** should be carried out once every year, and a more comprehensive survey once every three years, to check the condition of the main facade material, as well as more frequent quarterly checks on critical elements such as flashings, rainwater downpipes and gutters, and facade openings. Following unusual events (such as storms or floods), or when water seepage is observed through the facade, ad hoc inspection may also be needed. Facades being the protective envelope of a building, the cause of any defect should be determined and addressed as soon as possible to prevent the problem from worsening and affecting the vulnerable interiors.

The *inspection form and notes on maintenance* in Volume 1 are a good starting point to looking for defects.

If you cannot address the defect immediately, erect temporary protections such as netting or canvas sheet covers.

Plant growth on facade ornamental plaster mouldings.

BIRDS, INSECTS, VEGETATION

Disinfestation operations should be included as an integral part of the regular maintenance programme. In most cases, except for fragile building surfaces that may need to be treated first, disinfestation of vegetation and insect and bird colonies should precede facade maintenance cleaning operations. These organic colonies if not removed can cause serious damage to facades, or become a source of danger or annoyance (eg., wasp or bee nests). Resulting residues and moisture will also lead to vegetation growth.

Accumulated and hardened bird fouling can be softened with plain water before removal, though soak time should be minimised so as not to affect the building fabric.

Biological contamination by plant or moss growth is generally first removed by mechanical means such as cutting or scrubbing. This is followed by a suitable biocide treatment, to be judiciously applied as such treatments contain toxic chemical compounds. However, regrowth following disinfestation is quite common if environmental causes remain – the extent and rate of reinfestation is dictated by level of moisture, pH value and exposure to sunlight. Where possible, environmental causes should also be addressed, such as repair of defective gutters trapping moisture, or removal of landscape vegetation or water features located too close to the historic building facade.

***Left:** Wasp infestation on fairfaced brick facade. **Right:** Accumulated bird fouling.*

2 PLASTERWORK

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Overview

Plaster provides a protective layer on building exteriors. It is also easily worked by skilled artisans to create textures and ornamentation while helping to conceal less-than-ideal quality of the underlying wall material. It is usually manufactured as a powder and mixed with water to create a stiff, workable paste for application on building surfaces.

Facade ornamental plasterwork is one of the most visible and recognisable heritage attributes, giving character and identity to the historic building it adorns. It may be deployed as a pediment centrepiece, to articulate key elements such as gable ends and columns, or simply to give visual interest, such as hand-scored textured render. Apart from the aesthetic appeal, a further reading into the depicted motifs, stylistic provenance, material and craftsmanship, yields rich information about the building, including indications of the construction period, historic trends, original use, owner, architect, builder and artisans.

Clockwise from top left *- hand-tooled ornamental plasterwork found at: former Ford Factory (1941); shophouse pediment (c.1890s); St. Andrew's School (1940); former Anglo-Chinese School Cairnhill campus (1928)*

Mortar Mill at the grounds of Government House during construction, 1860s.

From the first permanent colonial structures such as early godowns, shophouses and residences, prewar built heritage in Singapore predominantly deployed lime-based plaster for external and internal wall finishes. Raw materials, local production and skilled artisans were available and relatively affordable. Lime plaster also had antifungal and antibacterial properties favoured for building in the warm, humid and disease-prone tropical environs.

Colonial Engineer John F.A. McNair, in his 1899 account *Prisoners Their Own Warders*, described the local production of lime and cement by Indian convicts to supply government projects in the mid-to late 1800s:

> *"Our lime and cement were made from coral, of which there were extensive reefs round the Island of Singapore… Coral is almost a pure carbonate of lime, and therefore very well suited for the purpose. It was broken up and heated in kilns constructed for the purpose. The cement was made from this lime, and from selected clay, in the proportions we had by careful experiments established, until we obtained a good and quick-setting article. It was made into small balls and then dried, and burnt in a special kiln, and afterwards well and finely ground and sifted by female convicts; its tensile strength was excellent."*

Lime kilns had been established since the early colonial period. Many were Chinese owned and worked by Hokkien and Teochew 'lime burners', mostly sited at coastal areas such as Punggol or Changi in proximity to shell and coral supplies, and where materials and products could be transported by boat. Indian-operated lime kilns were also found in the Rochore River/Serangoon area, giving rise to the place name of Kampong Kapor or Chunnambu Kambam ('Lime Village' in Malay and Tamil).

Indian builders introduced Madras chunam, a distinctively smooth, self-finishing render. This was found not just on Indian-built properties but also on the interiors of prominent civic buildings such as churches and government buildings. Lime from seashells was mixed with egg white and jaggery to form a paste, before mixing with water and soaked coconut husks – the fibres providing a reinforcement matrix that would improve tensile strength and reduce shrinkage. Upon setting, the rendered surfaces would be polished using rock crystal or rounded stone, and sometimes dusted with fine soapstone powder, to create a smooth, satin finish.

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Early lime plasters were much more porous and allowed moisture – which naturally occurs due to everyday exposure to the elements – to escape from the brick walls, thus keeping the building dry. (Recall in Volume 1: trapped moisture is a major source of defects in buildings)

Refer also to page 24 on "Common Issues Resulting from Misinformed Restoration"

While cement was also locally produced, it was likely used for mass concrete and early reinforced concrete, rather than cement plaster. The relatively low strength and porosity of early local bricks were better matched with '**breathable'** lime plaster, rather than high-strength and impervious cement plaster.

EARLY EXPERIMENTS WITH CEMENT PLASTER

Government House nearing completion, 1869.

A rare example of an early cement plaster historic building is the Government House (1869) designed by McNair, who described in detail the exterior plaster mix, which was believed to be able to better withstand heat and humidity: 2 parts Portland cement, 1 part white sand, and 2 parts powdered granite. It exemplified how early colonial engineers experimented with material use in designing for an unfamiliar climate.

Portland cement was a relatively new invention from Britain, afforded only in well-financed projects. While the long-term performance of the Government House's bespoke mix was not recorded, problems associated with the use of cement plasters and mortars on traditional construction with lime-based materials or lower strength bricks, such as cracking, shrinkage and excessive strength had already been widely observed by end 19th century.

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Top: *Salts are drawn up by water through the wall, which crystallize between the plaster and brick. The build-up of salt crystals can push against the plaster render, causing it to eventually delaminate.* ***Middle:*** *White powdery efflorescence are salt crystals that are carried by water to the surface of the plaster.* ***Above:*** *The presence of higher plants like ferns and fruit bearing plants likely indicate the presence of cracks, and the growth of these can aggravate the cracks.*

Common Deterioration

The types and extent of deterioration of the render will depend on:

- the composition of the mortar used,
- how it is applied,
- types and condition of the substrate,
- environmental exposure condition.

CRACKS

- Fine map-pattern cracks caused by shrinkage of the plaster
- Linear cracks are due to movement of the underlying walls or structure. Corrosion of embedded metals and reinforcements can also cause cracking of the render, often accompanied by rust stains.

DEBONDING / DELAMINATION

- Debonding can occur between the render and the wall substrate or within the render layers. Such failure may be caused by ageing of the plaster or salt crystallization attack. The origin of the salt could be from uprising damp from the ground or from within historic clay brick masonry units, especially those under-fired.

FRIABLE / ERODED SURFACE

- Powdery, friable and eroded plaster surfaces are brought about by the presence of water: physical erosion by rainwater, rising damp and resultant salt crystallisation attack within the plaster, or breakdown of the plaster's binder.

EFFLORESCENCE

- Efflorescence appearing on the surfaces of the plaster can be salt crystals that leach to the surface, originating from within the plaster or within the masonry.

BIOLOGICAL GROWTH

- Plant growth, as well as algae, mould and moss, are found in persistently damp and partially sheltered construction details or where there is presence of moisture and trapped salts.

COMMON ISSUES RESULTING FROM MISINFORMED RESTORATION

It is unfortunately common for early restoration works, especially those carried out in the 1980s to 1990s, for pure Portland cement-based render to be used to replace, patch or 'repair' deteriorated lime-based render.

Traditional lime-based renders are sympathetic towards old brick masonry walls, as such lime-based layers are softer and weaker than clay brick masonry. Due to this, deterioration more commonly occurs in the plaster, which can be easily replaced without damaging the masonry walls.

Portland cement-based renders, on the other hand, are much stronger and more rigid, often with high shrinkage rates. This type of render bonds very strongly to the masonry wall, making it difficult to be removed without damaging the masonry substrate during repair and restoration works. When applied over historic lime render, the cement render can also cause cracking and debonding of the historic lime-based layer.

Tell-tale signs of wrongly-executed repairs include dark greyish coatings underneath paint layers, spalling of plaster as it delaminates from the substrate, as well as debonded paintwork.

Diagnostics

The primary purposes of diagnosis are to:

- determine the durability of the existing render to be retained in the building,
- establish the extent of treatment or repair required for the existing render like consolidation, injection etc,
- design appropriate new render mix or select new render mix for replacement of damaged render,
- determine the causes of deterioration to the existing render,
- determine necessary preventive measures.

VISUAL AND TACTILE SURVEY

- Visual dilapidation survey - to identify and map out the various defects and deterioration as detailed in the previous section.
- Wall surfaces can be knocked by hand or with tools (such as metal bars or small hammers) to detect a ‘drummy’ hollow sound, to identify debonding or porous renders.
- Localised breakout inspection may be needed to establish plaster substrate condition and construction details

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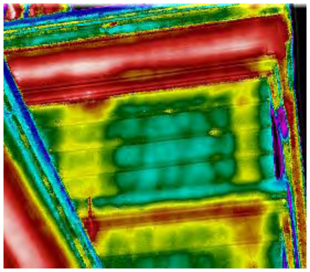

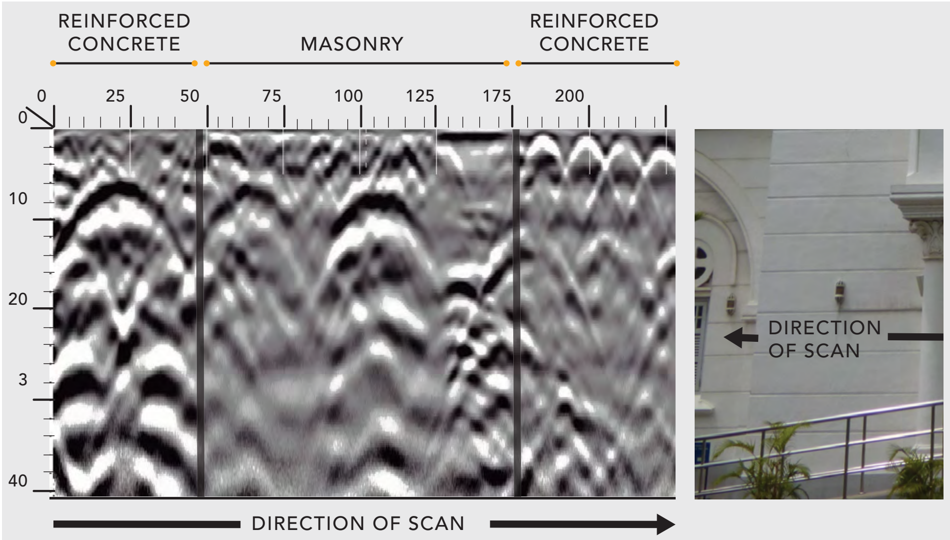

Left: *Infrared Thermography scans quickly identify areas of plaster that have hollowness, trapped moisture or construction anomalies, which show up as 'cold spots' against the rest of the facade.* ***Right:*** *Surface Penetrating Radar scans can help to identify the structure of the substrate without having to hack through the plaster.*

The Karsten Tube Test should be carried out in accordance with standards as set out by the International Union of Laboratories and Experts in Construction Materials, Systems and Structures (RILEM, from the name in French).

NON-DESTRUCTIVE TESTS

- **Infrared Thermography** to detect plaster hollowness or presence of trapped moisture.
- **Surface (Ground) Penetrating Radar** to identify hidden construction details, presence of moisture and trapped salts.
- **Pendulum Rebound Hammer** to measure the surface hardness, which shows the soundness and integrity of the render.
- **Karsten Tube Test** to test the plaster's moisture retention, and determine the durability of the existing render.

SAMPLING AND LAB ANALYSIS

- **Pull-off Adhesion** test to establish the adhesion bond strength of the render to the substrate or within the render layer itself.
- **Drill Resistance Measurement System (DRMS)** method, to measure the integrity of the render.
- **Petrographic Examination, Chemical Analysis** of samples extracted to determine their composition, quality and characteristics, such as porosity, presence of binder leaching or incompatible minerals, etc.

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Conservation and Intervention

PRINCIPLES

Conservation works on plaster should be limited to what is reasonably necessary to reduce or stabilize the rate of deterioration, and to enable the building to continue to fulfil its functions for a reasonable length of time. As much historic plasterwork as possible should be retained, to conserve the building's material authenticity while balancing performance and aesthetics.

Any intervention to the plasterwork should take into account:

1. the causes of deterioration,
2. compatibility of new and old materials,
3. long-term conservation of the whole building,
4. the appearance of repair.

Unless harmful for the building, imperfections, colour variations and patina should not be considered as dilapidation or defects. As an example, the decorative plaster in the photo above is not perfectly symmetrical, but this demonstrates its hand-made quality.

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Cleaning can be a very delicate procedure, particularly when dealing with painted or textured plasters. Cleaning methods need to be evaluated and tested case by case, ensuring there is no damage to the surface textures during the cleaning process.

Plasterwork Interventions:
Depending on the condition of the plasterwork, the works can range from cleaning to removal, repair, protection and reinstatement.

CLEANING

Plasters are particularly vulnerable to inappropriate cleaning methods. Coloured finishes and textures can be easily removed by careless cleaning, and lime plasters are particularly vulnerable. Therefore, the cleaning methods need to be carefully chosen with a full understanding of potential consequences.

REMOVAL

Removal of paint and coating is recommended when the plaster has been thickly overpainted with incompatible paints, the paint has deteriorated, the underlying plaster is in unknown condition, or there are excessive layers which obscure the architectural details.

There are several safe and effective techniques for removing paint or incompatible coatings from plaster surfaces, depending on the amount and type of coating to be removed. In general, the available methods are listed below, ordered from least to most invasive:

1. Non-contact (e.g., ultrasonic and laser cleaning)
2. Mechanical (e.g., brushes, sponges, scalpels and scrapers, micro sanding)
3. Aqueous (e.g., low-pressure sprayer, warm water, steam used to soften paint, poultice)
4. Chemical (e.g. ammonia carbonate, paint strippers)

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The images above show the sequence of application of ecofriendly paint stripper, combined with manual scraping, for removal of paint over plastered finishes.

Left: *Removal of paints by application of chemicals on the surface. The surface is wrapped in plastic to improve the chemical softening of paints.* ***Middle:*** *Manual paint removal for delicate relief details.* ***Right:*** *Removal of incompatible cementitious layers by chiselling.*

Refer to page 24 for 'Common Issues Resulting from Misinformed Restoration'

Latter-day renders and patches, such as the use of Portland-cement-based renders, are incompatible and adversely affect the performance of the historic plaster or wall. If the materials used are of **incompatible** composition or poor workmanship, they need to be removed to arrest any damage.

Debonded, loose and weak plaster beyond repair should also be removed. To avoid damage to the surrounding sound material, use controlled methods such as hand-chiselling or cutting using precision tools.

To maximise preservation of the plaster, only areas of hollow or deteriorated plaster should be removed and replaced.

Hollow or debonded plaster can be consolidated through injections of compatible grout. This is a specialised procedure which requires drilling small holes on the surface for insertion of tubes, and injecting the selected grout with light pressure.

The repair of damaged ornamental plaster should be carried out by skilled artisans.

REPAIR

Plaster that has become delaminated (i.e. hollow sounding) but is otherwise sound can be reattached by means of compatible grout injections, drilling stainless steel pin connectors and appropriate adhesive. This procedure is more frequently applied to ornaments but can also be used on plain plaster.

Wide cracks require removal of plaster so that the substrate can be inspected. If spalling is observed on plasterwork, it may be the result of corroded metal reinforcement embedded in the substrate. In this case, the plaster should be removed so that corrosion found on the exposed steel elements can be treated.

Hairline and small cracks don't require plaster removal, although if they are deemed unsightly, a simple skim coat is enough to fill the voids.

APPLICATION OF NEW PLASTERWORK

Once all deteriorated or incompatible plaster has been repaired or removed, compatible plaster should be reapplied to restore the facade. There are multiple considerations when looking for compatible plaster, including the chemical characteristics, water vapour permeability, resistance against salts, compressive strength, etc. While historic buildings are generally built with lime-based plasters and should similarly be restored with lime-based plasters, it is good to consult a materials specialist to verify the compatibility of the product you are considering.

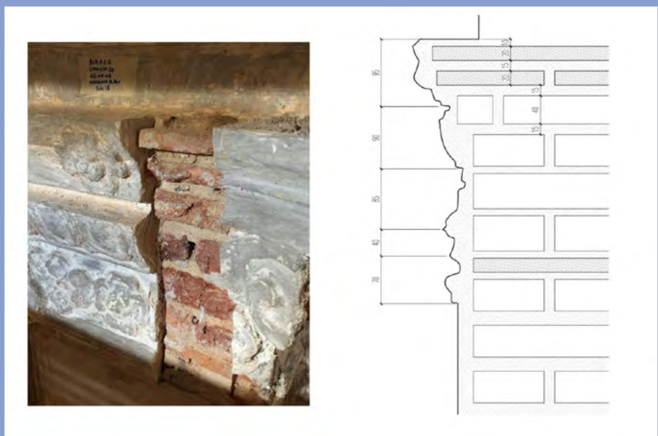
All plasterwork should be repaired or replaced to the same thickness, profile, finish level and texture as the existing plasterwork. Particularly for ornamented plaster, it is also advisable to engage skilled and experienced tradesmen, and work out samples before the actual plastering work to ensure a good match.

RECORDING AND REPLICATING MISSING ORNAMENTAL PLASTER

As good practice, ornamented plaster should be recorded for its exact profiles and patterns to facilitate replication work. Traditional methods include the use of profile gauges for running cornices, and grid-by-grid replication onto paper at 1:1 scale for complex profiles. In recent years, 3D scanning and silicone moulding have also become commonly used.

Ornaments that are missing or damaged beyond repair should be replicated based on an existing ornament of the same design. Usually, these are replicated in the same construction as the historic version, using brick to build up the base profile, and then lime-based plaster moulded by skilled artisans.

*Ways to document ornamental plaster for restoration - **Top:** Profile gauge measuring devices. **Above:** Handheld 3D scanning device.*



In the replacement of any decorative plasterworks or ornamental plaster such as the dentils, keystone, etc. the original construction details of the substrate should be followed as closely as possible. The image shows the built-up section of a decorative cornice.

In the best case scenario, there may be other intact ornaments of the same design from which you can replicate missing or damaged details. However, in some cases where the details are no longer available, you may have to refer to archival photographs to find out what it could look like.

Other methods include the use of fiberglass replication, though this should only be used selectively to respect the conservation tenet of material authenticity. In the case of Capitol Theatre, this was applied to reduce loading on the aged concrete structure - the original being heavy precast RC modules. In general, the restoration of historic hand-rendered ornamental plaster should still be carried out manually in situ by skilled artisans.

Mock-ups can be done to evaluate artisans skills before finally applying the work on the actual wall.

The image above shows the reinstatement of column fluting through a purpose-designed profile ruler, which was produced by measuring existing intact fluting.

Penciled grid over ornamental plaster to facilitate copying of details onto paper.

In the images above, the ornament has been measured by laser scanning and replicated in fiberglass using 3D modelling.

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Maintenance

Painting, more often than not with incompatible film-forming paint, is too often misused as a 'quick-fix' solution to defects on the plastered surface, but can worsen the deterioration down the road. Besides trapping moisture and hiding the condition, the thick multiple layers of paint can obscure the actual finish of the plaster, especially fine ornamental details.

Right: *Fine plastered details are obscured by thick coats of paint.*
Far right: *In some cases, past repainting applied over already peeling paint or defects can cause plain wall surfaces to appear textured or pitted, which can be unsightly.*

3 BRICK AND STONE MASONRY

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Overview

MASONRY CONSTRUCTION

Masonry refers to the technique of assembling building units, such as brick, stone, concrete blocks, etc., and binding them with a mortar to create a structure. In Singapore's historic buildings, brick is most commonly used, although there are also masonry walls constructed of stone (in particular, granite), concrete blocks, and hybrid combinations of different materials.

FAIRFACED FINISHES

While many historic masonry buildings in Singapore are rendered in plaster, a number are "fairfaced" in finish, which means that the surface of the masonry is exposed on the facade of the building. Due to difficulty in obtaining brick or stone that is consistent in colour and surface texture, historic fairfaced masonry finishes tended to be more expensive to construct, or made use of imported material.

The natural colours and textures of the masonry give a distinctive character to the building. In some cases, differently-coloured brick or stone are stacked to form a pattern, which serve as decorative features of the building. To preserve this character, fairfaced finishes should be kept exposed. If water-penetration is a concern, transparent UV-resistant coatings are available on the market to protect the surface while retaining its appearance.

Left: *Hybrid masonry walls constructed from brick and concrete blocks.* ***Middle:*** *Golden Bell Mansion at Mount Faber, constructed in an alternating combination of fairfaced and plastered brick popularly known as the "blood-and-bandage" style.* ***Right:*** *Shophouse with fairfaced brick facade painted over. The original texture, colour, and character of the building has become obscured and homogenized.*

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NOTES ON MORTAR, POINTING AND REPAIRS

Mortar functions to bond masonry units together. In traditional brick or stone masonry construction, lime-and-sand mortar was most commonly used due to its porous properties, which complemented the equally soft and porous brick or stone units.

Mortar joints can be prone to deterioration where water can soak into them. Over time, differential expansion and contraction of masonry and the mortar can also result in cracking between the two materials.

Cracks that occur along mortar joints (between bricks) can be repaired by injecting compatible mortar into the gaps. Besides chemical characteristics, the choice of mortar should also take into consideration its elasticity, since brick and stone undergo thermal expansion and contraction, requiring the mortar to be able to accommodate such 'thermal movements'. It is generally a good idea to consult a materials specialist to verify the compatibility of the mortar used.

The outermost 10-15mm of the mortar is known as "pointing mortar", which is generally designed to be weaker than the wall substrate. Once this become loose or eroded by weathering, replacement with compatible mortars – known as 'repointing' – will be required. Friable, or incompatible mortar joints should be removed and replaced with new compatible mortar.

Mortar repair for fairfaced masonry can be particularly tricky due to the varied surface colours and textures. Pigments such as powdered iron oxides may be added to mortar mixes to better complement the appearance of the masonry.

***Top:** Crack repairs by injection of compatible mortar into the joints restore the bond between units. Because the internal size of the crack is unknown, mortar should be pumped into the cracks until it overflows.*
***Above:** To repair the pointing, all loose or intact mortar should be carefully removed by manual chiseling by a skilled worker.*

***Far left:** During repointing, the mortar should be well compacted into the surface to ensure proper adhesion.*
***Left:** Tints are available on the market to colour and customize the mortar for a better match, but always test a few trial mixes to find the most appropriate one for your building.*

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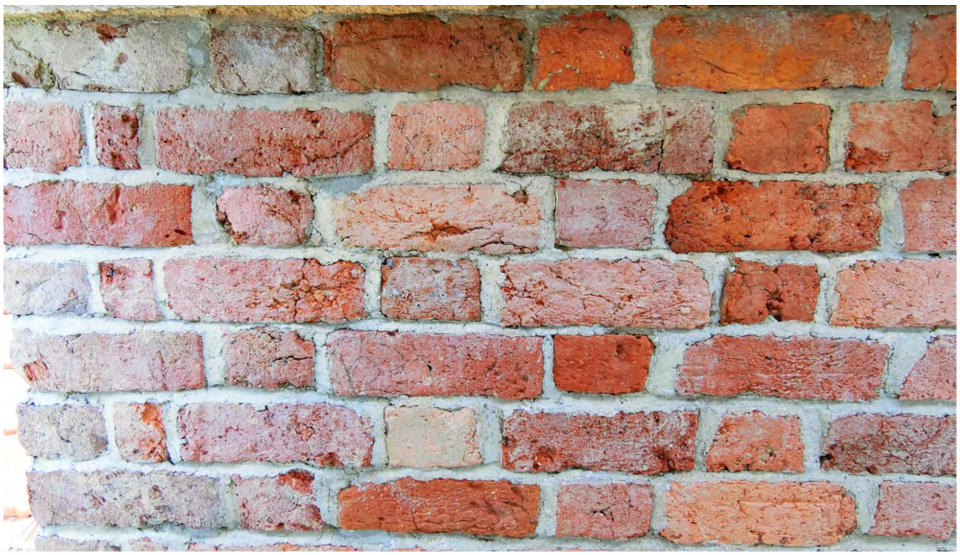
Overview: Brick Masonry

PRINCIPLES

One of the oldest known building materials, brick is formed by pressing iron-rich clay into blocks and then baking it. In Singapore, this clay was quarried mainly in the form of rocky shale, then crushed into powder and mixed with water. During the baking process, the water is driven off at 400°C, then at temperatures up to 1770 °C the clay particles fuse together to create a dense, solid block. When interlocked together and bound by mortar, this produces a robust, fireproof wall that can withstand the test of time.

The earliest large-scale brick production sites in Singapore were set up in response to the 1822 Town Plan that mandated buildings to be built of fireproof brick, terracotta-laid five-foot ways, and uniform tiled roofs. Between the 1820s and 1860s, kilns were set up mainly around the clay-rich Rochore-Kallang River, including the government-owned factory on Serangoon Road, which was run on Indian convict labour. Although the workers were trained to hand-form bricks and tiles of different shapes for mouldings, bricks and **lime mortar** produced here were still burnt and inconsistent in compaction, so buildings of the time were mostly finished in a coat of plaster.

Lime mortar:
For a history of lime mortar, refer to the history of plaster in Singapore.



The earliest bricks were fired in wood-fired kilns. Inconsistencies in firing temperature resulted in different 'wetness', density and thereby strength of the bricks. Clay was locally dug and, depending on the area, would produce bricks of different colours.

A number of buildings of the early 1900s imported bricks for use on the fairfaced brick facade, such as St George's Church (1911). Such bricks were available in a variety of shapes to be used as ornamentations, in addition to the regular brick wall finish.

With the invention of automated processes in the late 1920s, brick was machine-pressed into blocks using a die and stamped with the manufacturer's 'marks'.

The advent of modern technology revolutionalised the production method and quality of bricks. Beginning with explosives-extracted, steam-treated clay at the Borneo Company (later Alexandra Brick Works Ltd) in 1895, gradual improvements in brick appearance led to buildings in exposed 'fairfaced' finish, such as the Hill Street Fire Station (1909). Nonetheless, many other buildings still imported better-quality bricks from India, such as those at St George's Church (1911). Subsequently, machines were introduced in 1927 that automated the entire process from quarrying to crushing, mixing, forming and finally baking.

In the post World War II years, fairfaced brickwork regained popularity under pressure of stringent construction budgets. State-run buildings such as the Pasir Panjang Power Station (1953), public housing by the Singapore Improvement Trust and Housing and Development Board, and even corporate buildings such as the Macdonald House (1949) featured brick skins that conveyed standardization and expediency while retaining the traditional, hand-built, warm finish, to impart a sense of comfort and optimism in the nation-building years.

As an inexpensive alternative to brickwork infill walls, faience tiles, or clay wall facing tiles were used as cladding on hollow cement block-walls around the same time. One of the first local examples is the Britannia Club / former SAF NCO Club (1952), they were laid like wall tiles and finished with recessed pointing to simulate the appearance of fairfaced brick.

The brick-wall appearance of Britannia Club (1952) is simulated by lightweight brick-tile cladding.

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Common Deterioration

Top: *Materials like brick have high porosity and water absorbency, and tend to retain moisture. This can encourage biological growth (i.e., algae, moss, mould and plants), especially at the corners /ledges where water can easily be collected.* ***Above:*** *Surface erosion of brick due to rising damp, coupled with latter-day incompatible pointing that remains due to its higher strength.*

Notwithstanding that most masonry wall buildings in Singapore are plastered over and finished with paintwork, there are also old buildings with exposed brick facades. Given their nature of an exposed surface without any protective layer on top, such facades suffer more direct and destructive damage and defects.

Commonly encountered deterioration includes:

- Staining due to environmental soot or bird droppings
- Biological growth
- Cracks
    - along the mortar joints induced by movement of the building due to settlement
    - through the brick, which may indicate structural stresses
    - on the brick surface resultant from shrinkage or expansion of the brick
- Moisture from rising damp causing dissolution of salts within the clay brick material. The salts are brought to the surface, or encapsulated within the brick wall, resulting in surface erosion or expansion of the brick itself, which eventually degrades.
- Deterioration resulting from inappropriate past repairs, such as incompatible cement-based plaster coatings and sealant coatings, or painting over exposed brick, which can trap moisture within the walls.

Left: *Stepped cracks along mortar joints.* ***Middle:*** *Cracking through bricks can indicate structural stresses.* ***Right:*** *Cracks on brick surface resulting from shrinkage or expansion of the brick.*

Diagnostics

VISUAL AND TACTILE SURVEY

Identification and mapping of symptoms of brick deterioration, such as:

- Efflorescence and salt crystallization attack
- Types and widths of cracks
- Plant growth
- Stains
- Irregular or incompatible patches / coatings
- Surface erosion and crumbly surface

NON-DESTRUCTIVE TESTS

- **Karsten Tube Test** to measure the brick's tendency to retain water, by testing the capillary water absorption rate of the clay brick
- **Pendulum Rebound Hammer** to measure the surface hardness of the brick as well as the mortar joints, which shows the soundness and integrity of each component
- **Microwave Moisture** assessment to determine relative moisture content

SAMPLING AND LAB ANALYSIS

- **Speedy Moisture Meter**, involving drilling and extraction of brick samples to measure its moisture content
- **Drilling Resistance Measurement** through the brick to determine its integrity

In the Drilling Resistance Measurement System (DRMS) test, the force required to drill through the brick wall is measured to determine its strength at different depths and represented in the form of a graph.

Because drilling is required, this test is considered destructive and should be carefully considered for use on exposed brick surfaces.

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***Top:** The Pendulum Rebound Hammer is a quick, easy and non-destructive way to measure the strength of the brick's surface, but may be limited in measuring thicker walls. **Above:** Coring sections can be extracted for detailed study of the brick material, although such works are highly destructive.*

- **Salt Analysis** by extraction of salts samples, to determine the types and amounts of salts that are present, so that appropriate treatments can be made
- **Petrographic Examination, Chemical Analysis** of samples extracted to determine the composition, quality and characteristics such as porosity, soundness and firing degree of the clay brick

Conservation and Intervention

PRINCIPLES

The repair of exposed brickwork typically entails a combination of operations to fully restore the integrity, appearance and durability of the historic brick. Due to their clay composition, clay bricks are sensitive to acidity and abrasive action, especially historic, woodfired bricks that have inconsistent degrees of quality.

Most of the treatments listed in this section require the advice of a materials specialist, since the chemical composition of brickwork or terracotta may have implications on the compatibility of different products. The specialist will also be able to carry out tests to ensure effectiveness of the chosen product. Restoration of plastered surfaces over brick wall should follow the guidelines discussed in the "Plaster" section.

CLEANING

Dry brushing with non-ferrous brushes may be used as the first level of cleaning of brickworks. If that is insufficient, water jets with low pressure settings may be used to clean the surface of the brick.

Rotary jet cleaning, whereby a weak acid cleaning agent is applied to soften the bricks, followed by rotary jet blasting with glass powder on the lowest pressure setting, so as to remove inappropriate tough coatings and paint.

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Paint can be removed from exposed brick surfaces using alkali-free stripping agent, which is left for 1-2 hours, then removed using a paint scraper and a soft nylon brush dipped into water to take out any remaining residue. The process can be repeated a few times until all paint has been removed.

REMOVAL

Incompatible Coatings and Paints

Any existing inappropriate finishes such as paint and delaminated / incompatible plaster should be removed by manual scraping. Special non-corrosive paint stripping chemicals may be used so that no residue will remain in the brickwork substrate. Adjacents surfaces and elements should be protected so that the chemical treatment does not cause discolouration, staining and other deteriorations to these surfaces.

Rising Damp and Salt treatment

Rising damp treatment for fairfaced brick walls entails drilling of boreholes along the mortar joints and the injection of damp-proofing materials at an appropriate height and at regular intervals along the entire wall.

Salt treatment involves the removal of surface salts by vacuuming, followed by the application of a macroporous 'poultice'. The poultice is left for a period of time to absorb salts out of the wall and may need to be reapplied several times if the salt content is very high.

To counter rising moisture from the ground, boreholes of 20-25mm are drilled into the wall, preferably on the internal plastered side of the wall so as to not damage the external fairfaced brick finish. The holes are then injected with treatment mortar, which forms a waterproof barrier along the wall's length, thereby preventing moisture from travelling upwards.

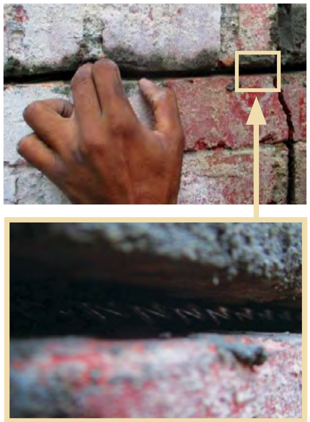
INTEGRATION REPAIRS

Brick Replacement

The defective brick should be carefully broken with chisel and hammer, and then removed manually. The replacement mortar and brick should match the existing ones in terms of strength, elasticity, texture and colour.

Left: *5-6mm-thick desalting poultice is applied and left to cure for three weeks before it is washed away. The surface is then tested for salts to determine the effectiveness of the treatment.* ***Right:*** *Brick replacement should be carried out using brick of similar strength and composition as the existing.*

In some cases, steel rods may be drilled into the area to secure the new brick.



Helical spiral steel bars are embedded between brick courses to provide binding strength to brick walls that are cracking apart.

Consolidant treatments are lightly sprayed across the surface, to stabilise fragile / friable surfaces over the loose material, to prevent further damage.

Brick Stitching

Helical spiral bar reinforcement provides stitching repair for masonry walls that have large cracks through several bricks. Pointing mortar underneath the affected areas of brick is chiselled and raked out. Stitching is then done by embedding stainless steel anchors into the mortar directly underneath the brick units, before sealing with an appropriate mortar.

Consolidant Treatment

Consolidant treatments for brick penetrate the surface to bind severely damaged masonry surfaces. Before carrying out full-scale application, trials on an inconspicuous small area should be done to ensure the product does not change the surface appearance or texture of the brick.

Anti-Hygroscopic Swelling Treatment

Swelling of bricks due to trapped moisture may be treated with anti-hygroscopic products. The product should be water-based, clear in colour, and not change the surface appearance or texture of the brick.

PROTECTIVE COATINGS

Water Repellent

While final paint coatings are generally not advised, fairfaced brick or terracotta may be made more durable by applying water repellent treatment, to reduce the absorption of water. It should be alkaline and UV-resistant, and have high diffusion and penetration capacities so that moisture within the walls can easily evaporate outwards.

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Maintenance

- Fairfaced brick walls should not be painted over as this can cause issues of deterioration in the long run, as the paint can trap moisture within the brick.
- As part of maintenance works, it is common for transparent, film-forming coatings to be applied over brickwork, to reduce water absorption and dirt accumulation. However, avoid surface coatings that are made up of acrylic-based or organic polymers, since they may deteriorate under ultraviolet (UV, i.e. sunlight) exposure, resulting in a whitish appearance or peeling. Some of such coatings may be designed for other materials, and can also aggravate deterioration by trapping moisture within the brick.

Inappropriate paint coating that attempts to mimic the appearance of fairface brick. A better solution in terms of material performance and aesthetic is to restore the brick wall rather than obscure its defects.

If the brick colour is extremely uneven, colour washes may be gradually applied in thin layers. However, it is should not be thickly applied over the brick as this can appear unnatural and unsightly.

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The Raffles Lighthouse (1855), built entirely in granite blocks, with quoin detailing.

History: Stone Masonry

The use of load-bearing stone masonry – arguably one of the oldest building materials in history – has been uncommon in Singapore since colonial times. This could be largely due to its relative scarcity as well as a lack of skills, know-how and resources in quarrying, cutting and dressing natural stone for building use. Among the earliest local stone buildings is the Horsburgh Lighthouse on Pedra Branca island, completed in 1851. According to historical accounts, "(the) stone … was procured from *(sic)* Pulo Obin … (and) was the best possible form of crystallised granite, fine grained, very compact and durable, grey in colour ... It occurs in large fluted boulders, and was wrought by the convicts by fire, or by blasting with gun-powder, or split by pointed chisels and large hammers." Granite was chosen for its high compressive strength, durability and salt-resistance – characteristics that could withstand the harsh environmental context of these sentinel structures.

Capitalizing on the ready availability of the material, Langdon Williams, Chief Surveyor of Singapore in the 1930s, built a house for himself on Pulau Ubin, constructed in loading-bearing granite stone with inset brickwork. The fine ashlar masonry work imparts a strong 'Arts and Crafts' architectural character and ornamental quality.

Pulau Ubin's name is derived from its original Malay name, Pulau Batu Jubin, which means 'Island of Granite Stones'. In the early days granite was quarried by convicts, as shown in the photo above. Later, the quarries were privately owned until their closure in 1999.

The fairfaced stone masonry walls on House No. 1 at Pulau Ubin, originally the house of Chief Surveyor Langdon Williams, displays the impeccable quality of the granite quarried from the island.

The use of stone on facades is not just limited to building walls, but also manifests as ornaments. Notable examples of stone ornaments include the imposing allegorical statuary in light pink Breccia Bottecino marble installed at the entrance portico of the former F.M.S. Railway Singapore Terminus (Tanjong Pagar Railway Station). These were executed by Italian sculptor Angelo Vanetti of the Florentine Raoul Bigazzi Studio, touted as 'the largest specialist in Italian Marble in the Far East'.

Stone columns of Stamford House adorn its prominent street corner entrance along the five-footway.

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Stone surfaces that are frequently exposed to moisture can become darkened. Particularly in the case of granite, salts trapped within the pores can lead to stubborn 'damp' marks which appear as darkened surfaces, since the salts retain water within the stone.

Surface erosion can occur due to exposure to acid rain.

Common Deterioration

Similar to brick masonry walls, exposed stone surfaces can be adversely affected by damages or defects. Stone is also naturally more porous and composed of mineral contents that can react adversely to alkaline or acidic contents in its environment, including the mortar.

Commonly encountered deterioration includes:

- Staining due to environmental soot or bird droppings
- Staining due to leached salts from adjacent mortar
- Biological growth
- Salts attack resulting from uprising damp
- Cracks
    - along the mortar joints induced by movement of the building due to settlement
    - through the stone block, which may indicate structural stresses

Diagnostics

Diagnosis of stone masonry is largely similar to that of brick, which may include the following:

VISUAL AND TACTILE SURVEY

Identification and mapping of symptoms of salt attack, cracks, plant growth, staining, surface erosion.

NON-DESTRUCTIVE TESTS

- **Karsten Tube Test** to measure the stone's tendency to retain water
- **Pendulum rebound hammer** to measure the surface hardness of the stone as well as the mortar joints
- **Microwave Moisture** assessment to determine relative moisture content

SAMPLING AND LAB ANALYSIS

Sampling extraction is generally not recommended as it can be difficult to patch the stone, and even harder to find replacement pieces for the damaged stone. Nevertheless, extractions may be made at non-high-key areas of the facade for further analysis, if there are extraordinary conditions to necessitate testing. Such tests can include:

- **Salt Analysis** by extraction of salt samples, to determine the types and amounts of salts that are present, so that appropriate treatments can be carried out
- **Petrographic Examination, Chemical Analysis** of samples extracted to determine the mineral composition, quality and characteristics such as porosity and soundness

Conservation and Intervention

Because of the varied textures and colours of stone, repairs can often appear quite conspicuous against the historic material.

PRINCIPLES

As best practice, any conservation works should be limited to what is reasonably necessary to reduce or stabilize the rate of deterioration. This is especially since the original stone quarries of historic stone are often no longer accessible, making the historic stone irreplaceable and near impossible to match.

Any intervention to stone should take into account:

- the characteristics and natural flaws of the stone,
- the causes of deterioration,
- compatibility and aesthetic match of new and old materials,
- long term conservation of the whole building,
- the appearance of repair.

Paint coatings obscure the stone surface and other conditions.

CLEANING

Stone is particularly vulnerable to inappropriate cleaning methods. Mineral contents of different stones can react with alkaline or acidic chemical cleaners, in worst cases resulting in extensive damage. Ideally, carry out small-scale trials on an inconspicuous corner of your stone surface, to understand how it will react to cleaning agents.

Most methods for cleaning of exposed brickwork can also be used on stone surfaces, such as:

- non-invasive (e.g., ultrasonic and laser cleaning)
- mechanical (e.g., vacuum cleaning, brushes, sponges, scalpels and spatulas, dry air abrasion, wet air abrasion)
- aqueous (e.g., low-pressure sprayer, warm water, hot water vapour, poultice)
- chemical (alkalis, acids, organic solvents, chelating agents)

REMOVAL

If the stone is affected by salt attack, the source of salt needs to be addressed, followed by desalting (through brushing or / and poulticing), and finally application of inhibitor chemicals to slow down the rate of salt attack.

Removal of paint and coating should be carried out by the use of manual scrapers or sanding machines without damaging the stone surface. If the paint is difficult to remove, the use of environmentally friendly, pH-neutral paint stripping chemicals can be considered. As with cleaning, all chemicals used on stone should be tested on a small area.

INTEGRATION REPAIRS

Where cracks are found on stone material, a careful assessment is needed. If cracks are found to be structural, advice from a structural engineer needs to be sought. Fractured stones are usually repaired with dowels or stainless steel anchors to pin the pieces together, and / or adhesives (mortar or resin based). If the crack is non-structural, it needs to be filled by grouting with compatible material (fine mortar or resins) to avoid the risk of water or other deposit ingress.

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Recall: Consolidant treatment (Vol. 1)

In extreme cases, stone can become friable due to damage of its binding material. **Consolidant treatment** can be considered to restore cohesion and give mechanical strength. Because there is a wide range of consolidant treatments available depending on the composition and purpose of the stone, it should be carefully chosen by a specialist to avoid altering the appearance of the stone and reducing breathability.

Finally, protective coatings can be applied to stone surfaces to reduce the deterioration, especially for those surfaces that are regularly exposed to dirt and elements. Nevertheless, they should be approached with caution as they tend to alter the appearance of the stone and in the worst case may even encourage other types of decay.

REPLACEMENT

This should generally be avoided as close matches are difficult to source, due to mineral differences in stone from different sources. Where absolutely required because stone is missing or damaged beyond repair, the replacement should match the existing block / panel in colour, quality and characteristics. Where possible, other intact pieces may also be removed from inconspicuous areas elsewhere in the same building, to be used for replacement.

4 SHANGHAI PLASTER

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Overview

Artificial stone – a building material that originated in Europe and was popularised in America as an economical substitute for natural stone masonry – is colloquially known as **'Shanghai plaster'** in this part of the world. It comprises exposed fine crushed stone aggregates in a cementitious binder presenting a textured or honed finish. Some have attributed the name to plasterers from Shanghai where European building crafts such as artificial stone flourished with the establishment of foreign concession zones in the period. Purportedly, these artisans came as part of the Chinese exodus to Malaya at the outbreak of the Sino-Japanese War, bringing along their skills and knowledge.

Right: *The Singapore seafront, until the 1970s, was well known for its signature skyline featuring Union Building, Clifford Pier, and General Post Office. Together with the Supreme Court and City Hall, and the Straits Settlements Volunteer Corps Drill Hall, these were all finished in Shanghai plaster.* ***Above:*** *Another notable example is the Chinese Protectorate Building.*

The popularisation of Shanghai plaster during the interwar decades marked significant progress in local building craft. Traditional lime stucco work could only be created in situ and depended heavily on skilled artisans. In contrast, Shanghai plaster offered the flexibility for on-site rendering and off-site precasting. Since it was a reconstituted material, repetitive elements could be replicated with relative ease by using a few well-built moulds and templates. The invention and mass production of white cement also opened up a new world of aesthetic possibilities – instead of the default dark grey of ordinary Portland cement, Shanghai plaster using white cement could now imitate almost any colour and hue of natural stone by adding mineral pigments.

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Top: *Cav Rudolfo Nolli and his masterpiece – the Shanghai Plaster facade ornaments at the old Supreme Court (National Gallery today).* ***Above:*** *Nolli and his Foochow artisan team in his casting yard at 47 Scotts Road.*

Favoured by owners and designers of important mercantile and government buildings for its attractiveness, versatility and durability, Shanghai plaster became synonymous with prestige and gravitas.

Many of Singapore's landmarks were impeccably finished in Shanghai plaster executed by the studio of Italian sculptor and specialist builder, Cavaliere Rudolfo Nolli. He apprenticed in his uncle's contracting firm in Milan, and was trained in 'cement-stucco' in Florence. Nolli's artistic talent and technical prowess are evident in the towering, elegantly proportioned colonnades and finely wrought acanthus foliage of their Corinthian capitals, crafted in remarkably homogeneous and well-compacted Shanghai plaster – mixed, rendered and honed by hand.

The popularity of Shanghai plaster continued after World War II and well into the late 1970s, in buildings as diverse as religious buildings – such as the Trinity Theological College Chapel at Mount Sophia and residential towers like Pearl Bank Apartments.

Shanghai plaster is commonly found on interwar period buildings including the Dried Goods Guild ***(left)****, and remained popular well into the 1970s, as seen in the Trinity Theological College Chapel (1969)* ***(middle)*** *and Pearl Bank Apartments (1976)* ***(right)****.*

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Top: *Severe efflorescence accumulating on the Shanghai plaster surface.* ***Above:*** *Staining and mould growth along ledges, where water tends to accumulate. Water ingress along the cracks has also resulted in plant growth and salt attack.*

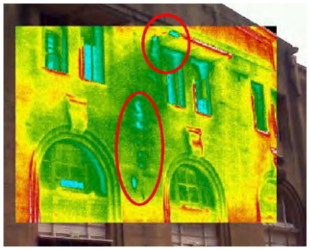
Common Deterioration

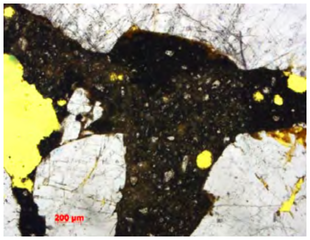
Due to the absence of a paint layer, Shanghai plaster can be subjected to different degrees and types of weathering and deterioration.

The most commonly encountered types of deterioration include:

- Shrinkage cracks, as with most concrete finishes. Ingress of water through the cracks can lead to dirt retention and efflorescence along the crack lines.
- Erosion of cement binder by rain, wind and abrasives, or acid rain, revealing rough, exposed aggregates. The poor maintenance practice of jet washing the facade with high pressure can also result in similar erosion.
- Environmental soot retention, due to its roughened texture. This often results in extensive and unsightly stains that are difficult to clean.
- Ad hoc patching of cracks, spalling or holes with poorly matched and incompatible mortar, largely due to poor understanding of the material.
- Application of film-forming a coating over the facade can further damage the Shanghai plaster surface, while water trapped behind the coating leads to moisture-related defects. Such coatings tend to be very difficult to remove, especially on textured Shanghai plaster.
- Corrosion of steel reinforcement or anchors in precast Shanghai plaster can cause cracking, rust staining on the surface of the facade and loosening of the panels.

Incompatible patching using modern-day pebblewash, which appears incongruous against the historic Shanghai plaster. The white 'stains' along the patch lines are salts efflorescence arising from water ingress through the seams.





Top: *Areas of debonding or trapped moisture appear as 'cold spots' on Infrared-scanning cameras.* ***Above:*** *Petrographic examination under the microscope can inform the materials, sizes and mix ratio of the binder and aggregates, although samples will need to be cut from the facade.*

Diagnostics

VISUAL AND TACTILE SURVEY

- Visual identification of symptoms, such as cracking, bowing, excessive efflorescence, corrosion stains, deformation, etc., as a first stage of diagnosis. The pattern and distribution of the defects should be mapped out on a building plan so that the actual failure mechanism of deterioration can be determined.
- A simple and quick method to identify cavities behind Shanghai plaster is through mechanically tapping on the surface to detect a 'drummy' hollow sound.

NON-DESTRUCTIVE TESTS

- **Infrared thermography** to detect the presence of cavities or trapped moisture behind the finish layer.
- **Surface penetrating radar** to scan reinforcement details and other anchoring details, particularly for precast panels. This can also be used to assess corrosion of embedded reinforcements, especially to determine whether spalling is prone to occur if left untreated in the long term.

SAMPLING AND LAB ANALYSIS

It may occasionally be necessary to extract samples of the deteriorated tiles or mortar, especially where the exact composition of the Shanghai plaster is required to source for repair materials. One of the most useful tests is **petrographic examination** of Shanghai plaster under a microscope at different magnifications. The petrographic examination should be performed by an experienced petrographer or geologist.

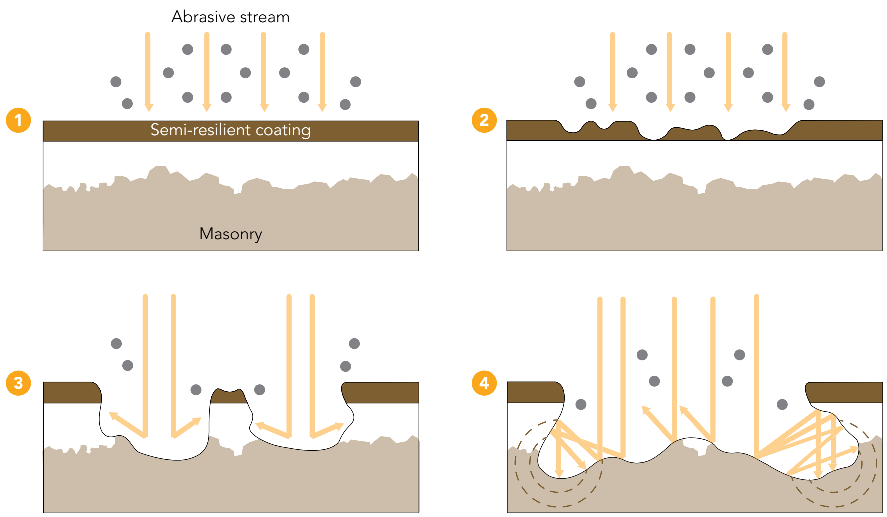
Conservation and Intervention

Top: *Permanent scarring of Shanghai plaster due to abrasive action by high-pressure water jet.* ***Above:*** *Shanghai plaster corroded by high acidity cleaning product.*

PRINCIPLES

Although Shanghai plaster is composed of stone and cement, conservation works on it can be much more complicated than that on its component materials separately, as there are three key concerns:

- **Sensitivity to moisture and acidity:** Shanghai plaster is a partially porous material and chemically alkaline. Chemical reactions due to excessive moisture e.g., rainwater infiltration and acid exposure, will weaken its material structure and cause surface erosion.
- **Sensitivity to mechanical vibration:** As it is not materially homogeneous like natural stone, Shanghai plaster is susceptible to crazing and fissuring caused by excessive levels of mechanical vibration, such as that from adjacent construction work. Such cracks are not only aesthetically undesirable but could lead to more serious problems or become conduits for water infiltration that will result in other forms of deterioration.
- **Sensitivity to abrasive action:** Other than causing permanent visual disfigurement, excessive abrasion of the protective surface cover may result in an elevated risk of crazing and fissuring, leading to damage caused by subsequent water infiltration.



Loss of cement binder and granite aggregates due to excessive abrasive action.

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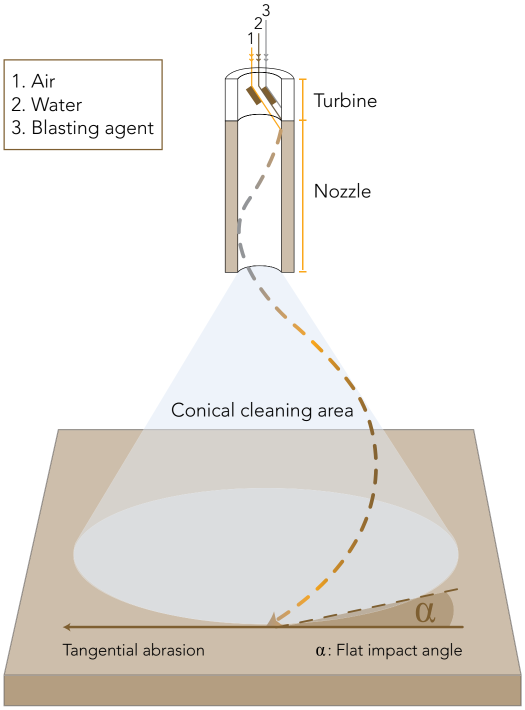
From right: *The principle mechanism of low-pressure rotary jet cleaning; Shanghai plaster cleaning in progress by trained worker.*



Top: *Fine-grained sand used as blasting agent for rotary cleaning.* ***Above:*** *Damaged Shanghai plaster revealed under thick coats of paint, which was removed by means of rotary cleaning.*

CLEANING

Due to the stone content of Shanghai plaster, acidic and caustic cleaners damage it. High-pressure water jet cleaning must also not be done, as it will damage the surface layer of the cement binder and aggravate the detachment of the granite chipping aggregates. The negative outcome of abrasive cleaning can be drastic and may result in the loss of shine and colour of surfaces, detachment of the aggregates, leaving behind permanent 'graffiti' on the facades.

A recommended gentle and effective mechanical means of cleaning is the use of **low-pressure wet grit blasting** (between 0.1 to 3 Bars) using a rotary cleaning head such as a Rotec or Jos system. Dry ice pellets may also be used.

REMOVAL

To remove deeply penetrated stains or paint coatings, chemicals such as appropriate paint stripper and a variety of solvents such as EDTA may be judiciously used.

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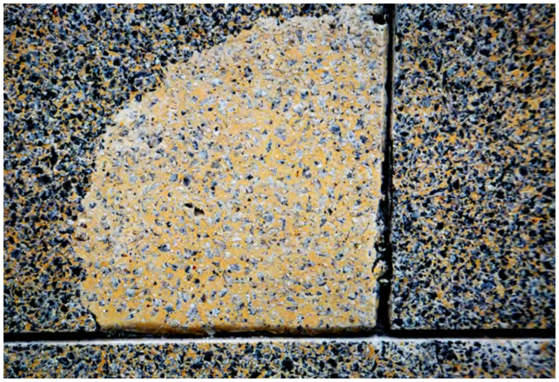
*Bearing in mind that half or more of a weathered Shanghai plaster surface is exposed aggregate, careful aggregate selection **(far right)** and size grading is extremely important for patching. Even differences in aggregate angularity (rounded pebbles vs. crushed stone), or mismatch in ratio of mortar to aggregate, will be noticeable in the final repair **(right)**.*



Repair methods for Stone Masonry in Chapter 3.

The colour of the repair patch materials and stones will need to be ascertained to blend with the existing colour.

INTEGRATION REPAIRS

In general, **repair methods for stone masonry** are also applicable to the repair of Shanghai plaster. Nevertheless, the main difficulty of Shanghai plaster repair is that patching has to be carefully matched to the existing material, as badly executed patching cannot be concealed beneath a coat of paint. Successful repairs of Shanghai plaster consider the cement matrix colour, stone aggregate size, coloration, distribution and finishing, which may be discerned by petrographic examination prior to any repair works.

CONSOLIDANT TREATMENT

After careful patching repairs are completed, a consolidant product may be required to be applied onto the friable surface to restore its material strength. The product should not cause any discolouration or enhancement of the Shanghai plaster appearance and must allow the transmission of water vapour.

PROTECTIVE FINISH

Coatings such as a 'breathable' microporous water repellent (different from a sealant) may be required for Shanghai plaster that has extensive map-pattern cracks. These are usually shrinkage cracks due to very high cement content, or inconsistencies in the original plaster mix and workmanship. Do note that some products can result in colour alteration or enhancement of the finish, so carry out a trial application in a small area to assess the aesthetic impact.

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Maintenance

- Painting over Shanghai plaster for aesthetic reasons often has detrimental effects, as the historic character becomes obscured under characterless whitewash and loses its vibrant visual character.
- Caulking, as traditionally used on fissures and cracks on plastered and painted surfaces, should not be used for Shanghai plaster.
- The natural weathering of Shanghai plaster produces a patina that does not warrant its large-scale replacement, unless severe cement matrix problems or rusting reinforcement bars have caused extensive scaling or spalling of the finish.

After rainfall, uneven patches may appear on wet Shanghai plaster finishes, due to different rates of water absorption between historic surfaces and the new patch repairs. The 'map-pattern cracks' as shown in the photo may also become more pronounced.

A row of shophouses with Shanghai plaster facades at Bukit Pasoh - the tactile and historic character is lost when painted over, since they appear like plain plastered facades.

5 CERAMIC TILING

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Overview

In Singapore, historic ceramic tiles as facade finishes were predominantly found on late 19th to early 20th century townhouses, shophouses and bungalows. These were mostly manufactured ceramic tiles in tin-glazed decorative designs. As there was no local tile production, these were all imported and supplied via agency houses - the earliest, such as Minton tiles, being from England. Other sources included Belgium (e.g., Gilliot & Cie, S.A. Helman Ceramic), Germany and France. Industrially produced ornate tiles of this period still required manual processing at some stage, such as hand-tinting.

As European tile production took a hit during the World War I, Japanese tile manufacturers such as Danto Kaisha and Fujimiyaki Tile Works made inroads into the local market. More affordable and comparable in quality, these became prevalent from the interwar years, with designs in European styles as well as variations with auspicious Chinese motifs such as pomegranates and peonies, to appeal to the local Chinese clientele.

Left, Middle: *Colourful Art Nouveau floral designs were a popular choice for dadoes on shophouse and townhouse inner-leaf facades.* ***Right:*** *Azulejo or Delft-influenced blue-and-white tiles on the facade of St Joseph's Church.*

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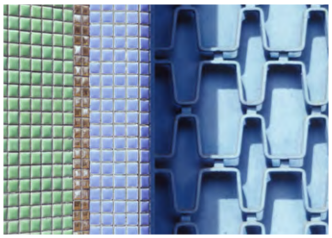
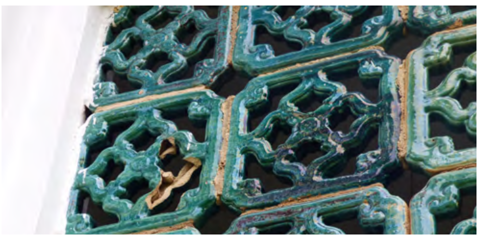
Left, Middle: *Customised glazed terracotta units were tailored to create a set of four coat-of-arms on the Tanjong Pagar Railway Station main facade, featuring the initials of the Federated Malay States Railway.* ***Right:*** *Majestic Theatre facade*

Facade decorative tiles on prewar buildings were usually applied selectively as accents, such as dadoes flanking the main entrance on the verandah or five-foot-way inner-leaf facade, or feature panels adorning pilasters and parapets. An exception was the Tien Yien Moh Toi (1929, later Majestic Theatre), featuring a Chinese-Art Deco facade design composed entirely of Belgium-made ornamental tiles supplied by French agency house A. Clouet & Co.

In the postwar years of austerity, plain coloured tiles were favoured instead of ornate designs. By the 1960s, tiles, especially mosaic, had become a common exterior finish, appreciated for their flexibility, durability, 'self-cleaning' properties and modern aesthetics, with entire buildings clad in the material. The material came in varying textured surfaces, glazing and tones, and offered the possibility to create wide-ranging patterns. For mosaic, the tiny units meant it could adapt well even to unconventional forms.





Left: *Mosaic tiles on the walls of Khong Guan Biscuit Factory.* ***Middle:*** *Glazed terracotta ornamental vent tiles or blocks with Chinese motifs originated from south China and were widely used since the late Qing dynasty. These were installed as parapets or vents, decorative features that also facilitated natural ventilation.* ***Right:*** *An example of a commercial building putting mosaic to good use is Peninsula Plaza (1981) with its elegant contoured frames clad entirely in the material.*

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Top: *Historic mosaic tiles uncovered after removal of insensitive latter-day cladding works.* ***Above:*** *Crazing in the surface glaze resulting in moisture ingress through the glaze. Over time, mould growth has occurred within the cracks.*

While tiles used on facades are mostly glazed due to the weather exposure conditions, there are also unglazed varieties of ceramic tiles typically used for interiors. Refer to Volume 6 (Interior Elements – Floors) for more information.

Some defects can be manmade, such as insensitive renovation works to install services.

Common Deterioration

Depending on the particular clay mix, or types of pigments used within the tiles, ceramic tiles may differ in durability. The most commonly encountered forms of deterioration are cracking, buckling and loosening tiles, although these may arise from various different factors:

Deterioration of plaster bedding behind tiles

- Cracking or surface erosion of pointing mortar.
- Prolonged seepage due to ingress of water along damaged pointing can cause leaching of the bedding plaster, resulting in tile debonding.

Deterioration of tiles

- Attack of silica content in tiles by alkalis in the bedding plaster, upon moisture ingress. Past 'repairs' with cement-based mortar, which is alkaline, can also result in similar long-term issues.

Movement due to thermal flunctuations or building settlement

- Since ceramic tiles are generally more brittle and hard compared to the cement-based adhesive layer, shrinkage of the cement bedding or the underlying plaster can cause the tiles to crack or buckle.
- Sudden crazing, or fine cracking within the glaze layer. Be careful about identifying crazing as a defect, as this may sometimes occur as a natural effect of the firing process. Nonetheless, such cracks are usually very fine and harmless, although spalling of the glaze layer has, in rare cases, also occurred.

Man-made defects

- Physical damage due to accidental knocks or insensitive ad hoc works.
- Mismatched tiles from inappropriate patching repair

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The first stage of diagnosis involves a visual survey and mapping of observable defects such as cracking.

Diagnostics

VISUAL AND TACTILE SURVEY

- A visual survey, supplemented by historical research, should first be carried out to identify as much as possible the tile vintage, material, and manufacturing information.
- Visual identification of symptoms, such as cracking, buckling, popped tiles, etc., as a first stage of diagnosis. The pattern and distribution of the defects should be mapped out on a building plan so that the actual failure mechanism of deterioration can be determined.
- A simple and quick method to identify cavities behind adhered ceramic tiles is through mechanically tapping on the surface to detect a 'drummy' hollow sound.

NON-DESTRUCTIVE TESTS

- **Infrared Thermography** to detect the presence of cavities or trapped moisture behind the finish layer
- **Ultrasonic Pulse Echo** to assess the integrity of the adhesive beneath the tiles

SAMPLING AND LAB ANALYSIS

It may occasionally be necessary to extract samples of the deteriorated tiles or mortar for further analysis, such as:

- Petrographic examination to analyse the integrity of the glaze layer and condition of the bedding and its interaction with the tile body. The petrographic examination should be performed by an experienced petrographer or geologist familiar with ceramic tile and mortar bedding.
- Thermal and moisture expansion of the tiles
- Water absorption of the tiles

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Conservation and Intervention

CLEANING

Ceramic tiles are favoured for both indoor and outdoor use because they are relatively low-maintenance, robust and easy to keep clean. Usually, daily dry wiping or cleaning with warm water is enough to keep your tiles looking good as new for a very long time. However, even with glazed finishes, the ceramic material is still inherently porous hence can absorb water, dirt and oil if not immediately cleaned up.

Tough stains can be removed using non-soap-based household cleaners and soft brushes. Avoid cleaning agents that are acid-based or abrasive as these will react with the tile surface and cause discolouration, scratches or hazy surfaces that will be near impossible to remove.

REMOVAL

Removal of paint and coating should be carried out by use of manual scrapers without damaging the tile surface. If the paint is difficult to remove, the use of environmentally friendly paint-stripping chemicals can be considered.

Slightly damaged historic tile should be repaired and left in place to avoid collateral damage caused by removal.

INTEGRATION AND CONSOLIDANT REPAIRS

Attempting to remove one tile can cause damage to surrounding tiles, so it may be better to leave a tile in place if it is only slightly damaged. If a corner has cracked off, it can be easily reattached using epoxy glue. Similarly, chipped edges can be repaired by applying patches of coloured epoxy, or tinted mortar matching in colour to the surrounding area.

For unglazed tiles, surfaces that have worn off or become powdery or pitted can be treated using specially formulated silicic acid consolidants, and followed with siloxane repellents, which must be carried out by a conservator or tile specialist. Such a treatment binds the surface and makes it less porous, so that it becomes less susceptible to damage, but it can cause permanent discolouration to the tile.

Mortar joints that have become loose or eroded should be slowly removed or chiseled out by hand. Once the defective mortar is cleaned off, wet the areas to be repaired and apply grout matching the old in colour and consistency.

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To find matching replacement tiles, try to identify the manufacturer and date of the tiles, which may be imprinted on the back of the tiles. Other ways of finding out this information include looking for historic catalogues or other buildings with similar tiles.

REPLACEMENT

Where there is a need to replace seriously damaged or missing historic tiles, **matching tiles** that were salvaged or from old stockpiles should be used. Otherwise, replica tiles requiring special fabrication can be challenging to source or manufacture.

As a rule of thumb, unless there is extensive damage with many missing or broken tiles, it is best practice to leave the tiles alone without replacing them. To replace a single tile, first carefully remove all the grout around using a handheld grout saw. Avoid using electric cutters as these may cut into the surrounding tiles or cause them to come loose due to vibration.

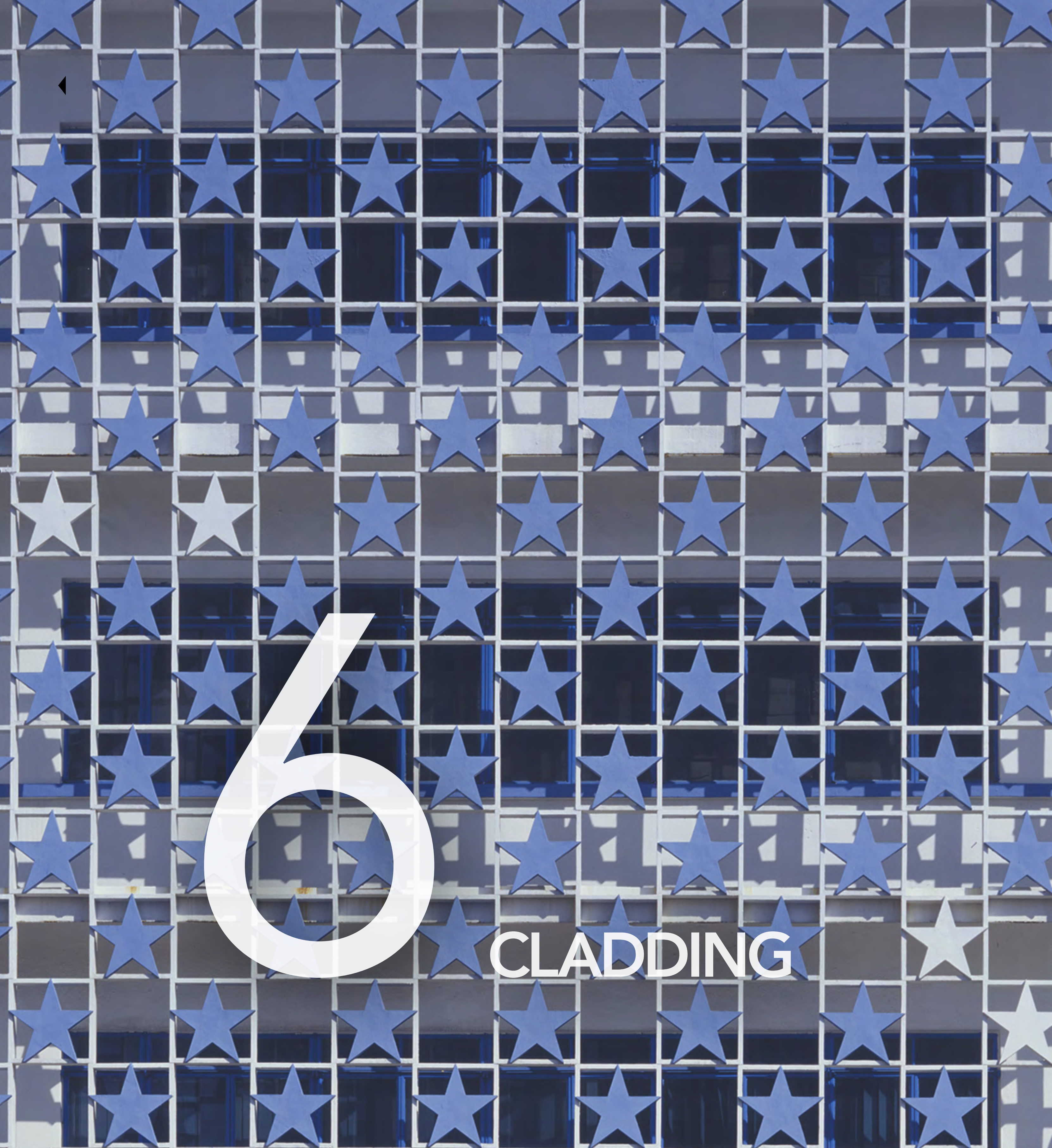
DISMANTLING AND REINSTATEMENT

Sometimes it may be necessary to dismantle part or all of the tiles, for example for wall substrate repair, structural strengthening and so on. Tile types and designs should be first documented and mapped out in detail. Tile joints should be carefully cut with a precision cutter prior to dismantling. Dismantling should be carried out by manual chiseling of the mortar bed. If there are no loose or missing tiles where the dismantling can begin, it may be necessary to have a 'sacrificial' first tile - preferably at an obscure location. Particularly for ornamental or mural tiles, each unit should be tagged to record its relative location, and wrapped for protection before warehouse storage.

The tiles will usually undergo bench restoration in a workshop, before delivery to the site for reinstallation. The tile layout is physically marked onto the bare substrate, before each each piece are returned to their original location according to the pre-dismantling documentation and tagging.

Maintenance

Ceramic tiles, particularly glazed tiles which are more commonly used on external walls, are designed to function without the need for coatings, as they are fired with a tough and relatively waterproof 'skin'. Although there are many commercially available coatings on the market, many will wear away or peel off, requiring frequent reapplications. This process of reapplication may cause damage to the tiles, especially if the coating can only be removed using harsh chemicals.



6 CLADDING

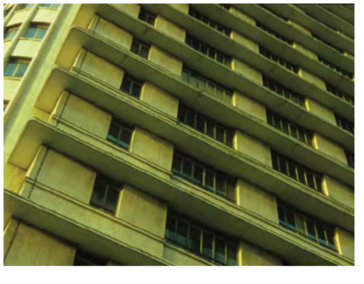
Overview

The 1950s marked the modernization of the building industry, with experimentation in building materials, their production methods, construction techniques, and consequently the appearance of postwar modern architecture. This effect is most visible in the development of facade cladding. These are prefabricated non-load-bearing architectural elements that are attached to the building structure to form external surfaces, as opposed to facades traditionally formed of structural elements such as masonry walls, or applied finishes such as plastering. Cladding systems also include components such as windows, doors, gutters, roof lights, vents and so on. This chapter is focused on stone, glass and metal cladding.

STONE CLADDING

Modern quarrying and cutting technology enabled the use of natural stone as a veneer, departing from its traditional structural role. Italian Travertino Romano panelling in the MacDonald House, the first postwar large office building, and the NAAFI Britannia Club were strategically deployed as an accent finish on the otherwise low-key fairfaced brick facades. The finely honed panels impart a subtle sense of luxury in a resource-strapped era. Most strikingly, the former Asia Insurance Building designed by Ng Keng Siang was clad entirely in pale beige travertine panels, rising 18 storeys high as Singapore's tallest skyscraper for a decade after its completion in 1959. Granite facing became popularised from the 1950s through the 1960s, seen in the ashlar work on the former Singapore Polytechnic Lecture Theatre at Prince Edward Campus, as well as Mount Emily and River Valley Road public swimming pools. Completed in 1976, OCBC Building heralded a new era of stone curtain wall cladding in very large panel size, dramatically defining the building's monolithic, sculptural silhouette.

Below: *Travertine-clad facade of the former NAAFI Britannia Club.* ***Below middle:*** *Impeccably-crafted sunshading fins of the former Asia Insurance Building.* ***Below right:*** *Stone ashlar veneer on the front facade of the auditorium of the former Singapore Polytechnic.*



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As advancements in building technology enabled openings to become larger and larger, the fine line between windows and walls became blurred over the years. Refer to upcoming Volume 5 – Windows & Doors for more indepth history of glazed windows.

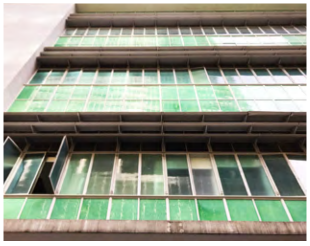
GLASS CLADDING

Up until the early 1920s, windows were mainly in timber and typically louvred, and only the most affluent could afford any form of glass in their windows. This changed with the development of sheet-glass production on an industrial scale, which made glass suddenly stronger, more affordable and available in exponentially larger sizes. Concurrently, reinforced concrete was maturing rapidly as a building technology. By the 1930s, the use of flat-slab floors and set-back columns enabled buildings to have continuous, floor-to-floor frameless openings for **glazed windows**, and later fully glazed facades.

Despite the glare from the tropical sun, transparent glazing continued to be popular for its sleek appearance, although developments in plate glass technology made it easier to bear. Glass with film coatings, such as Calorex Glass by Messrs. Chance Bros. and Co. (1930s), as well as green-tinted non-actinic glass let in soft light while protecting interiors against direct sunlight.

In the late 1950s, glazed facades were revolutionized with the introduction of stainless steel or aluminium frames for prefabricated glazing panels. Known as 'curtain walls', these were preassembled in the workshop before being hung directly onto the building frame, considerably reducing the length of time needed for onsite assembly.

Concurrently, opaque structural glass slabs under names like 'Vitrolite' were imported into Singapore. These were new forms of wall facing, backed by masonry substrate, and were touted to be resistant to grease, abrasion, warping or fading, and imparted a sleek, glossy finish to their buildings. Vitrolite offered an inexpensive new way to decorate the exterior – at the Commercial Union Assurance Building on Telegraph Street (1957), black Vitrolite panels were arranged in alternating bands with marble slabs, producing an eye-catching frontage. Original Vitrolite panelling is now extremely rare in Singapore and recognised as a historic architectural finish worthy of preservation in many countries, including the US.



Top: *The George Street Telephone Exchange (1953), a rare surviving example of a building featuring Vitrolite panelling, in jade green colour.* ***Above:*** *The well-lit 6-storey high atrium space of the Afro-Asia Building (1950s) was enabled by curtain wall technology.*

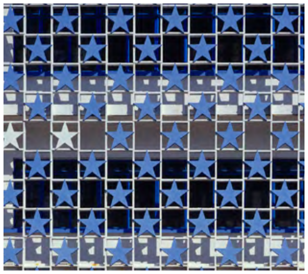
METAL CLADDING

Metal eggcrate clad over an older shophouse facade instantly lends the building a dignified appearance.

Prior to the proliferation of metal-clad buildings from the late-1970s onwards, metal facade elements were limited to lightweight systems such as sunshading louvres and screens. Both steel and aluminium are choice materials for their lightness, strength and ductility, with the latter having an added advantage of being corrosion-resistant. Being mass-fabricated in standardised extrusions and profiles, architects could readily select the desired designs off manufacturers' catalogues – like the gigantic vertical louvre blades of the Singapore University Department of Physics lecture halls. These also provided an inexpensive way to update the appearance of older buildings by simply erecting a metal sunshading screen over the existing facade, as in the case of many shophouses in the late 1960s.

Beyond their utilitarian function, the crisp profiles and detailing of metal screens impart a distinctive character. The Lea Hin Building (1964) employs a combination of square eggcrates and star motifs, derived from its company logo, in their shading devices. These motifs are arranged in a chequerboard pattern, as a playful advertisement for the firm's metal building components.

Full-fledged metal cladding made its appearance during the early 1970s, as seen on the overhead bridge at the Change Alley Aerial Plaza, which featured prefabricated rolled steel profiled sheets. The 1974 Telok Blangah Substation is one of the earliest curtain wall buildings, clad in a medley of solid and perforated bronze anodized aluminium and glass modules. The gloss and texture of these new materials give rise to a sleek, even futuristic quality, projecting a progressive post-independence architectural identity.



***Left:** The use of metal fins and star-shaped motif cut-outs on the Lea Hin Building creates an imageable identity. **Right:** The Telok Blangah Substation sleekly clad in bronze anodized aluminium and glass cladding.*

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ISSUES OF INSTALLATION

- Regardless of cladding material, mechanically fixed panels can suffer from cracking, loosening or buckling due to restraint around the anchoring points. This occurs when there is thermal expansion or contraction in the panels, which has not been considered in the design of the anchors.
- Rust formation around framing brackets can also exert pressure on the cladding panel, resulting in buckling or breakage.
- Sealant and putty between the panel and frame are likely to become damaged over time due to exposure to the environment. When this happens, water ingress at crevices can also lead to damage to the panels, so sealants need to be frequently replaced.
- Missing pins and corrosion of bolts and brackets can also result in complete dislodgement of the panels.

When inspecting your cladded facade, consider both the fixing details and the structural condition around it, as damage in the brackets may be caused by movement of the structure around it.

Generally, the diagnosis of jointing fixtures is visual-based, identifying symptoms such as cracking, bowing, corrosion stains on the panels, as well as corrosion and damage to the fixing brackets. Videoprobes may be used to inspect the condition of the mechanical anchors, bolts and plates that are hidden behind the panels.

Left: *Water ingress through mortar joints can affect the adhesion of the panel to the substrate, resulting in debonding.* ***Right:*** *Cracks on the panel near the frame, possibly arising from movement of the building.*

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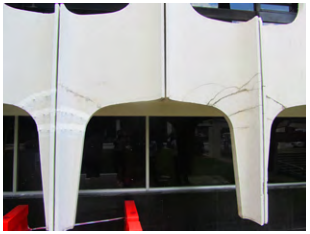

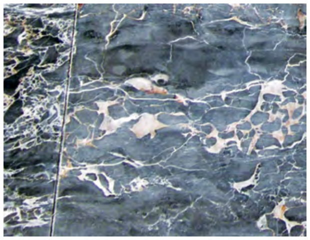

Above: *Areas of damage should be demarcated by taping or other means, so as to determine the extent of works needed.* ***Middle:*** *Whitish discolourations on stone surface may indicate leaching of salts from the mortar bedding.* ***Top:*** *Cracking of the stone finish due to physical stress inherent from the design.*

Common Deterioration: Stone Cladding

The deterioration symptoms of stone cladding are generally similar to those of stone masonry. Commonly encountered deterioration includes:

- Staining due to environmental soot or bird droppings
- Biological growth
- Cracks
  - along the fixing joints induced by movement of the building due to settlement
  - through the cladding, which may indicate structural stresses

Similar to ceramic tiles, stone panel cladding tiles that are adhesive-bonded to the substrate could also be affected by the mortar bedding, which is usually cementitious-based. This can manifest in the form of:

- White efflorescence (powder) on the stone surface that leaches from the mortar due to prolonged moisture ingress
- Debonding of cladding panels
- Discolouration and staining of stone panels in contact with the mortar due to salt attack resulting from rising damp. Particularly with granite panels, salt trapped within the pores can lead to water marks or stubborn 'dampness', as salt retains water.

Diagnostics

VISUAL AND TACTILE SURVEY

- Visual identification and mapping of cracking, bowing, excessive efflorescence, corrosion stains, deformation, etc.
- For adhesive-mounted stone panels, debonding may be detected by tapping on the surface of the stone panel to detect a 'drummy' hollow sound. However, as the panels may be quite thick (as compared to ceramic tiles), this may not be an entirely reliable option.

NON-DESTRUCTIVE TESTS

- **Infrared Thermography** to detect the presence of cavities or trapped moisture behind the stone cladding layer
- **Ultrasonic Pulse Echo** to assess the integrity of the adhesive beneath the cladding

SAMPLING AND LAB ANALYSIS

It may occasionally be necessary to extract samples of the deteriorated panels or mortar for further analysis, such as petrographic examination to analyse the integrity of stone and, where applicable, the underlying mortar. The petrographic examination should be performed by an experienced petrographer or geologist.

Conservation & Intervention

Black onyx stone panel in polished finish to showcase the natural tonality and veins. Particularly for stone claddings originally in polished finish, surface etchings and other surface stains may be removed by buffing the surface. However, polishing should be carefully considered as it involves removing the top surface of the stone.

PRINCIPLES

As best practice, any conservation works considered should be limited to what is reasonably necessary to reduce or stabilise the rate of deterioration. This is especially since the original stone quarries of historic stone are often no longer accessible, making the historic stone irreplaceable and near impossible to match.

Any intervention to stone should take into account

- the characteristics and natural flaws of the stone,
- the causes of deterioration,
- compatibility and aesthetic match of new and old materials,
- long term conservation of the whole building,
- the appearance of repair.

CLEANING

Stone is particularly vulnerable to inappropriate cleaning methods. Mineral contents of different stones can react with alkaline or acidic chemical cleaners, resulting in a foggy appearance, especially if the stone panel has a polished finish.

It is recommended to carry out small-scale trials on an inconspicuous corner of your stone surface, to understand how it will react to cleaning agents.

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REMOVAL

Salt efflorescence on the stone surface may be naturally occurring after rain and can be easily dry-brushed or vacuumed off. If there is excessive salt attack that continues to surface, the source of salt needs to be addressed, followed by inhibitor treatment to slow down the rate of salt attack.

Removal of paint and coating should be carried out by the use of manual scrapers or sanding machines without damaging the stone surface. If the paint is difficult to remove, the use of environmentally-friendly, pH-neutral paint-stripping chemicals can be considered. As with cleaning, all chemicals used on stone should be tested in a small area.

Latter-day renders and patches are often incompatible and adversely affect the performance of the historic stone. Commonly noted incompatible patches are cement-based pointing, or in some cases, entire missing panels are patched using cement plaster. These incompatible cement renders can exacerbate salt attack-related damages, and will need to be removed to arrest any damage.

INTEGRATION REPAIR

Where **cracks** are found on stone material, a careful assessment is needed. If cracks are found to be structural, advice from a structural engineer needs to be sought. Fractured stones are usually repaired with stainless steel anchors to pin the pieces together, and / or adhesives (mortar or resins based). If the crack is non-structural, it needs to be filled by grouting with compatible material (fine mortar or resins) to avoid the risk of water or other deposit ingress.

In extreme cases, stone can become friable on the surface, for example due to erosion or salt attack. **Consolidant treatment** can be considered to restore cohesion and give mechanical strength.

Generally, thin cracks are not recommended to be repaired as the repair can look even more unsightly. To prevent water ingress through the cracks, a UV-resistant water repellent coating may be applied over the surface.

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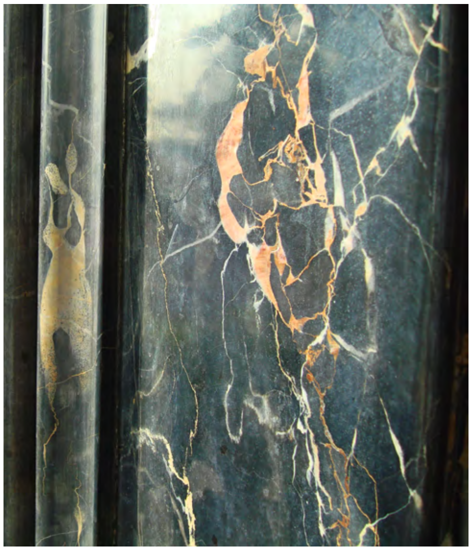
REPLACEMENT

This should generally be avoided as close matches are difficult to source, due to mineral differences in stone from different sources. Where absolutely required because it is missing or damaged beyond repair, the replacement should match the existing block / panel in colour, quality and characteristics. Where possible, other intact pieces may also be removed from inconspicuous areas elsewhere in the same building, to be used for replacement.

Maintenance

- Do not patch every crack that you find on the stone surface. This is because thin patches will deteriorate or fall off rapidly, and have to be reapplied often.
- Hairline cracks may be left in place if they are not at risk of opening up further, since the repair lines can look unsightly and may even entail further damage in the process of grouting.

Many types of stone may have natural crack lines and fissures, that contribute to its natural appearance, and should not be taken as defective. Finding out the type of stone you have on your building will help to inform what is the best course of action.



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Common Deterioration: Metal Cladding

Depending on the type of metal, different types of deterioration will occur:

Iron and steel

- Rusting and corrosion due to exposure to water and oxygen in the environment
- The iron content of the metal, enabled by water, combines with oxygen to form an oxide, thereby weakening the bonds of the metal. Rusting when left untreated in the long term can result in extensive corrosion, whereby the metal loses its integrity.

Anti-corrosion products designed for iron and steel may stain copper surfaces, and are not suitable for use.

Copper and copper alloy (brass and bronze)

- Similar to iron, copper combines with oxygen in the presence of moisture to form a rust coating called a 'patina', which can quickly occur in climates with high humidity such as Singapore's.
- Although the patina is formed as a natural rust, it serves to protect the underlying material from further deterioration and appears as a beautiful sheen that conveys the age of the material. This process goes through several changes, turning from brown to black and finally blue or green.

Chemical attack resulting in breakdown of copper

- Exposure to acid, such as from acid rain / runoff, plant growth, contact with timber substrates
- Alkali from surrounding mortar
- Inappropriate cleaning products

Metals are also susceptible to galvanic corrosion, which is the result of dissimilar metals being in contact, such as aluminium fasteners being used to fix copper sheets. In the presence of water, ions from one metal can travel to the other, depending on their properties, resulting in corrosion of the former.

Multiple signs of damage in the metal cladding, including missing units, warpage, dislocation, staining and corrosion.

Diagnostics

- Most defects can be detected visually, such as leaks, discolouration, rust, stains and corrosion.
- The diagnosis process for metal facade, which is also applicable to roofs, includes understanding the properties and characteristics of the metals and their finishes and coatings.

Conservation and Intervention

RUST REMOVAL

- Minor rusting may be removed by mechanical brushing with a wire brush, or low-pressure sandblasting.
- Extensive rusting can be removed by 'pickling' or immersing old ironworks in warm dilute phosphoric acid. However, this can only be done off-site.
- Components that cannot be dismounted can be treated with commercially available 'rust remove' gels or pastes based on phosphoric acid.
- Alternatively, rust may be converted or stabilised using orthophosphoric acid-based, tannic acid-based rust converters.

REPAIRS

- Minor cracks and tears may repaired by welding, brazing or soldering new matching metal to the cleaned surface. However, it is important to note that only specialist tradesmen should be engaged for these works. Larger areas may be cut off and replaced with similar material.

PROTECTIVE FINISHES

- It is essential to apply protective coatings immediately after rust and corrosion have been treated, as rusting can occur soon after due to exposure to moisture and oxygen in the atmosphere. Appropriate protective coatings include:
    - silicate-based corrosion inhibitors applied prior to final primer and paintworks,

  - primers based on red lead, zinc phosphate, or zinc chromate applied prior to painting,
  - final polyurethane paint.
- Besides replacement and repairs, often the colour of the metal sheet would have to be matched. Painted metal sheet may be matched with matching colour with coating.
- Patinated surfaces require additional treatment in order to match the colour. Artificial patination may be carried out with the appropriate chemical treatment, which would accelerate the formation of patina on the surface of the metal sheet.

DESIGN ENHANCEMENTS

In case of corrugated galvanized iron sheets, there is a tendency to rust around fixings, in the form of crevice corrosion. This may be repaired by inserting a slip-sheet with matching profiled corrugated sheets with provision for sufficient overlap and proper fastening.

Maintenance

- Deterioration of metal surfaces can be prevented by preventing rusting, through periodic cleaning, rust removal and treatment.
- Coatings can be used as the first line of defence against rusting. Do also consider applying anti-rust primers or other treatments prior to final coating.
- Identify the type of metal the building component is constructed in, which will determine what kind of cleaning / repair method is appropriate.
- Metals are susceptible to galvanic corrosion, which is the result of dissimilar metals being in contact in the presence of moisture. Aluminium, steel and galvanised fasteners must not be used on copper sheet for this reason. Run-off from copper sheet will corrode aluminium and steel elements.

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Common Deterioration: Glass Cladding

Damage to glazing panels is most commonly caused by mechanical impact and improper use of cleaning methods and chemicals, but may also arise from inappropriate design or poor installation.

Common form of deterioration includes:

Fracture

- The strength and resistance of glass to stress is dependent on the chemistry and microstructure, thickness and size, annealed or tempered as well as the nature of the load. Historic glass, typically annealed, is strong in bending, but internal flaws that occur naturally due to the production process may result in shattering in case of sudden load.

Glass corrosion

- Corrosion in glass results from frequent exposure to moisture, typically due to condensation. Pure water from condensation and pickup of soluble contaminants makes it slightly acidic. This results in leaching of alkalis from the surface of the glass. The surface thus becomes more porous and more susceptible to further attack. This process, known as 'crizzling', may weaken the glass over time.
- Exposure to acidic or alkaline environments can also result in similar effects.

Condensation on the surface of glass occurs when there is a large temperature difference between the two opposite surfaces of the glass. Although condensation may not be a defect in the short term, collection of condensate around the edges of the glass may seep into crevices resulting in biological growth.

Discolouration and surface etching

- Abrasion, contaminations, rust stains and corrosion from surrounding frames can lead to discolouration of the glass.
- Alkaline residue from concrete will attack glazing. Acid also degrades the surface of glass. This residue etches the surface of the glass resulting in a loss of transparency.

Diagnostics

VISUAL AND TACTILE SURVEY

Defects such as breakage, leakages at joints and discolourations can usually be detected visually.

NON-DESTRUCTIVE TEST

Identification of type of glass in-situ using non-destructive portable **X-ray Fluorescence** (XRF).

SAMPLING AND LAB ANALYSIS

Sampling for in-laboratory chemical analysis can provide some information about the date of manufacture and explain the causes of defects and damage.

Conservation and Intervention

REPLACEMENT

Due to different textures and colours of glass attributed to different production methods (which may no longer be used), close-matching replacements may be difficult to find. For this reason, replacement should only be considered if the glass panels are seriously damaged or if matching glass cannot be salvaged from less prominent areas of the building.

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Maintenance

- Protection of surrounding frames / brackets from moisture is essential to ensure long-term durability, since deterioration of glazing panels often arise from issues with the frame. Rust should be regularly cleaned off, as rust build-up can cause pressure on the glass, resulting in cracks and breakage.
- Putties and sealants around glass undergo natural wear and tear due to weather exposure. Resealing is required on a periodic basis.

7 GLASS BLOCKS

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Overview

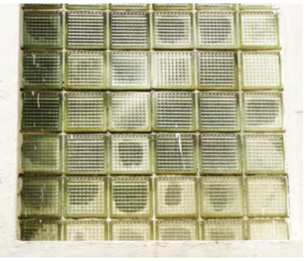
The predecessor to the modern-day glass block was first invented in the 1880s by Swiss architect Gustave Falconnier. Known as the Glasbausteine or 'glass brick', it was blown while hot into a mould, creating a cavity. Unfortunately, due to issues with stability, the Glasbaustein never really took off, although it was exhibited internationally, such as at the 1893 Columbian Exposition.

Glass blocks, or glass bricks, are hollow blocks made by sealing two squares of glass together at their edges. Each square of glass is poured in molten form into a mould on an automatic press machine, which gives it its distinctive texture. Glass block walls are constructed by stacking and binding with mortar.

The vogue for glass blocks came to Singapore around the late 1950s, when both commercial buildings and domestic homes found a penchant for its ability to provide an abundance of light and the illusion of space. By this time, modern reinforced concrete buildings were already the norm – buildings were built in frame constructions that had lightweight, autonomous walls in all possible materials. Glass blocks, such as 'Insulight' Hollow Glass Blocks by Pilkington Bros. Ltd., were particularly suited for facade walls as their textured surfaces provided great light diffusion against the tropical sun, while their hollow cores insulated against heat and exterior noise.

Despite being expressed as infill walls, glass blocks had the added advantage of high compressive strength. Glass block walls could span across great vertical heights of facades, making them popular for lighting up vertical spaces like stairwells. They were also popular as decorative features that could be inset into walls without a frame, such as for clerestories as well as skylights.

Right: *Winstedt Road postwar civil service flats with a central glass block feature wall that lets in natural sunlight into the staircore.* ***Far right:*** *Facade cross motifs composed using glass blocks double as toplights at St Joseph's Church.*



Stains on the internal surface of the glass blocks, possibly due to infiltration of moisture through cracked or broken mortar joints.

Common Deterioration

Glass is prone to chipping and crack when exposed to mechanical and physical force. However, glass blocks are relatively strong and normally would only break in case of extreme force.

Hence, the key defects of glass block have more to do with the nature of their installation, particularly the mortar joints, similar to masonry. Ingress of water into the mortar between blocks, through cracks or along deteriorated pointing, can cause leaching and formation of salts efflorescence on the surface of the glass blocks. Prolonged seepage can also result in deterioration of the mortar and resultant debonding of the block.

In hollow glass blocks, infiltration of air and moisture may lead to staining and condensation. Sealing failure at joints often allows penetration of moisture. This is likely to occur in hollow blocks made out of two parts sealed together. This failure tends to occur when the mortar and glass interface develops fine cracks.

Diagnostics

Most defects on glass blocks can be easily identified visually. Fine defects on glass blocks may be viewed optically with the help of good lighting and a portable microscope.

Right: *Broken glass block.*
Far right: *Painted surface on a glass block.*

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Latter-day ad hoc 'replacement' using a piece of wired glass. Missing blocks should instead be inserted with a matching replacement unit to restore not just the appearance but also structural integrity of the glass block wall.

Conservation and Intervention

REPAIR

- Repointing of mortar joints is the most commonly required intervention. Mortar joints that have become loose or eroded should be slowly removed or chiselled out by hand, before repointing in mortar matching the original. Extreme care is to be taken to eliminate any use of water for cleaning and repairing of the sealant.

REPLACEMENT

- Depending on the design of the glass blocks, it may be difficult to find replacements. Replacement will hence likely require specially fabricated reproductions that can be extremely expensive to manufacture. For this reason, replacement should only be considered if the glass blocks are seriously damaged or if matching blocks cannot be salvaged from less prominent areas of the building.
- Great care is to be taken to protect other blocks over a larger area than where the damaged block is located. To replace a single block, the block will have to be broken mechanically, taking care to isolate the damage by taping or protecting the block and surrounding areas. All damaged mortar should be removed by hand before the application of new, compatible mortar, and insertion of the replacement block.

Maintenance

- Although glass blocks are relatively easy to keep clean, do take special note of the joints, especially those facing external areas, since these are more porous and may be prone to algae and mould growth.
- Sealant and joint failure should be addressed as soon as possible, before any water ingress.

8 PRECAST CONCRETE

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Overview

Above: *1927 advertisement of mass produced precast concrete vents and parts.* ***Right:*** *Nan Hua High School at 2 Adis Road (1941)features a series of cantilevered precast RC fins.*

While reinforced concrete manifested mainly as building structure, small areas of facades incorporated concrete in their construction. Advancements in construction technology led to mechanisation and standardisation and allowed for factory prefabrication of building parts such as balustrades, vents and window awnings. The corresponding penchant for geometric clean lines of the Art Deco movement during the interwar years pushed the requirements of this technology, producing wafer-thin, continuous cantilevering fins that wrapped horizontally around building perimeters.


Left: *People's Park Complex (1973) - the podium is clad with rusticated concrete panels, designed such that each could be lifted manually by one or two workers.* ***Right:*** *Singapore Polytechnic at Prince Edward Road (1972) - concrete panels are used as infills for the structural frame. Slender sunshading fins express the buildings structural and design datum.*

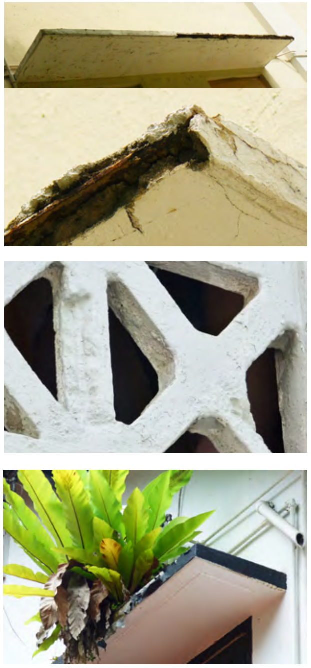

Top: *Breathable facade screen wall at SGH Housemen's Quarters (1950s).* ***Above:*** *Wing On Life Building (1975) - precast 'twisted' RC panels doubling as screen wall and structure.*

The postwar years saw the peak of concrete prefabrication technology. Spurred by a need for standardisation, and in response to the idea of the tropical building envelope serving as an environmental filter, precast ventilation blocks in a variety of designs and combinations were developed for building facades. Mass-produced in the factory and assembled on site, they were an attractive but practical building decoration that filtered heat and glare while improving air movement, particularly for a time before air conditioning was affordable.

Precast concrete building elements of the post-independence years grew immensely in scale. While earlier components, such as the precast cladding panels of People's Park Complex (1973), were small and light enough for a single worker to manually lift, they eventually required mechanised cranes to attach on building facades.

Common Deterioration

While early precast building parts such as fins and vents were typically painted over, care should be taken to find out if your building was originally intended to be finished in exposed concrete, such as Golden Mile Complex (1973). Many such finishes have today been painted or coated over with incompatible coatings to hide surface defects and blemishes, for ease of maintenance, but this has given rise to a host of other issues, including trapped moisture.



Top: *Corrosion of the embedded steel reinforcement resulting in spalling of the concrete around it.* ***Middle:*** *Previously-spalled vent block coated in paint.* ***Above:*** *Plant growths may be indicative of cracks, which should be addressed promptly to prevent corrosion of the embedded steel reinforcements.*

The most commonly encountered forms of deterioration include:

Cracks
Similar to plaster, cracks can appear on the surface of the concrete, which can be due to shrinkage, movement or corrosion of the steel reinforcement.

Corrosion of embedded reinforcing steel

- Corrosion of steel reinforcement or anchors in precast concrete, that can cause cracking, rust staining on the surface of the facade and loosening of the panels. In the worst case, spalling may also occur.

Defects in the concrete

- Carbonation, where carbon dioxide in the atmosphere reacts with the concrete from the surface towards the center. When the carbonation reaches the steel reinforcement, the concrete no longer protects the steel from corrosion.
- The inherent use of unsuitable materials within the historic concrete mix, such as sea sand containing chlorides, has been known to accelerate the rate of corrosion of the steel.

Efflorescence

- Water infiltration through the concrete salts leaching from within the concrete material, surfacing as white powdery efflorescence.

Biological growth, staining

- Plant growth, as well as algae, mould and moss are found on persistently damp and partially sheltered surfaces.
- Especially in case of exposed concrete, which is porous, environmental soot and biological growth can be common.

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Recommendations given in RILEM 104-DDC for identification and classification of defects may also be adopted for diagnosing concrete defects.

Diagnostics

VISUAL AND TACTILE SURVEY

- Visual identification and mapping of defects such as efflorescence, spalling, cracks, plant growth, staining, and irregular or incompatible patching

NON-DESTRUCTIVE TESTS

The quality and soundness of the concrete can be checked using the following common techniques:

- **Ultrasonic Pulse Velocity** measurement
- **Rebound Hammer** test
- **Penetration Resistance** (Windsor Probe) test
- Construction details and any internal features in the concrete, including details of the steel reinforcement, can be established using surface or ground-penetrating radar.

SAMPLING AND LAB ANALYSIS

Corrosion activity can be assessed for rate and risk of spalling, but requires extraction of samples for the following tests:

- **Half-cell Potential**
- **Resistivity**
- **Linear Polarisation**
- **Depth of Carbonation**
- **Petrographic Examination and Chemical Analysis**

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Exposed reinforcement of spalled concrete is cleaned and treated with anti-corrosion coatings, before replacement grout is applied.

Conservation and Intervention

Historic facades that have exposed concrete require greater care, as the exposed surfaces are more porous and sensitive to damage caused by inappropriate techniques. Nevertheless, it is prudent to seek specialist advice on the most appropriate systems, and carry out trials in inconspicuous areas before embarking on full-scale restoration works. This is especially important considering that the numerous proprietary systems available on the market may not be designed for historic concrete and may be capable of inflicting unintended permanent damage to the concrete surface.

CLEANING

The three primary methods of cleaning concrete are water-based systems, abrasive systems and chemical systems, including poultices. However, similar to plasters, ornamental or textured finishes may be easily removed by careless cleaning, so the method should be carefully chosen.

Particularly for exposed concrete surfaces, a recommended gentle and effective mechanical means of cleaning is the use of **low-pressure wet grit blasting** (0.1 to 3 Bars) using a rotary cleaning head such as 'Rotec' or 'Jos' system. Dry ice pellets may also be used.

For more details on low-pressure wet grit blasting using rotary jet systems, refer to page 57 of this volume.

REMOVAL

- To remove deeply penetrated stains or paint coatings, chemical means such as appropriate paint stripper and a variety of solvents such as EDTA may be judiciously used.

INTEGRATION REPAIRS

Depending on whether the concrete is painted or exposed, the method of repair should consider the final appearance on the surface. Generally, precast concrete that will finally be painted is more tolerant to different methods, since some repairs can be highly conspicuous on the surface and appear unsightly.

- Large cracks may be injected with fine grout like cement, lime or epoxy depending on the original concrete mix.
- Spalled concrete due to corrosion of steel reinforcement bars will need to repaired by rust removal and anti-rust treatments, before the concrete is patched.

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- As the cement mix of most historic concrete is of lower strength, the repair materials or patch-up concrete should be compatible with the historic concrete in terms of appearance (texture and colour), thermal and moisture expansion, elastic modulus and strength, which can be determined by laboratory testing. Care should be taken to ensure the new patch is well-compacted to the old, so that moisture cannot penetrate.

PROTECTIVE AND PREVENTIVE FINISHES

- Fine hairline cracks do not need to be repaired if paint is to be applied. For exposed surfaces, such cracks can be treated with an impregnating (and non-film-forming) water repellent without being repaired.
- Penetrating sealers may be considered to fill pores and fine cracks and make the concrete resistant to water and dirt.
- Depending on the historic concrete mix, compatible paints should be used for painted surfaces, to act as a protective coating.
- Detected rusting of embedded steel that has not caused spalling can also be stabilised by non-destructive methods, which can be advised by specialist applicators. Such methods include:
    - **Cathodic Protection**, whereby a sacrificial metallic surface is applied on the external to prevent corrosion of the embedded steel.
    - application of a topical migrating corrosion inhibitor.
    - re-alkalisation of the concrete by soaking in alkaline solution, to prevent corrosion caused by carbonation.

Regular cleaning should be carried out to remove environmental soot, algae and mould.

Maintenance

- The application of impregnating sealers, silane / siloxane-based water repellers, or acrylic coatings can ease future maintenance by minimising absorption of water, and by extension dirt retention and biological growth. However, such sealers may cause permanent discolouration to exposed concrete and should be spot-tested before full-scale application.

9 TIMBER FACADES

Overview

Unlike shophouses in other parts of the region, such as those found in Malacca and Penang, timber is hardly used as a facade material on Singapore's shophouses, and even less so on other permanent buildings. Instead, plastered brick, concrete and stone were more often chosen in compliance with fireproofing requirements of the 1822 Town Plan. Nevertheless, timber facades were still used in areas outside the city centre, mainly on vernacular architecture such as kampong houses (still seen in areas such as Kampong Buangkok and Pulau Ubin), Malay houses, traditional Chinese Wayang stages, etc. Timber facades have also been used in combination with other facade materials on historic bungalows, as well as for temporary sheds and outhouses.

Typically, timber facades are thin and lightweight, taking the form of opaque sidings made from wooden boards joined by tongue-in-groove joints, or screens with carved wood or timber strips laid in lattice-pattern. In the traditional Malay House, the wooden board facade is an evolution from woven bamboo or nibong walls. Used in combination with columns and beams made from local hardwoods such as Chengal and Meranti, the organic nature of the material meant that the facade walls were usually designed to be replaced periodically without affecting the structure. The flipside to this is that such buildings are relatively more difficult to preserve in their entirety, since the building would have gone through multiple rounds of replacement walls and panels.

Left: *Overlapping wooden boards on the facades of the former farmhouse at Dairy Farm Road.* ***Middle:*** *A rare existing example of timber sidings used for institutional buildings, at the Pasir Panjang English School. The timber lightweight infill spans between RC columns which are expressed on the facade.* ***Right:*** *Tan Kong Tian Temple Stage at Jalan Kebaya (1919). The timber structure sits on masonry piers, raised above ground moisture.*

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Specific methods for replacement, repair and treatment of damaged timber is covered in greater detail in Volume 5 (Doors & Windows).

Deterioration and Diagnostics

There are a number of agents of decay that will affect timber due to its physical and chemical composition. The single most damaging agent is water or excessive moisture, which may result in a host of different damages, including:

- Cracking / Splitting along the grain of wood due to irregular drying and wetting,
- Decay caused by fungal growth in the presence of moisture,
- Termite attack / Insect attack,
- Weathering of the surface due to frequent exposure to rain and direct sunlight. This shows up as surface roughening, splitting, bleaching and erosion.

Special attention should be paid to detect the following:

- Signs of termite trails
- Trapped moisture, poor drainage and persistent dampness including biological growth
- Presence of insects (e.g., ants, bees) and frass
- Failure of paint works

Deteriorated timber siding and poorly executed ad hoc repair using incompatible material.

Conservation and Intervention

Care should be taken to first check for the presence of lead paint before sanding. Should such be found, specialists advise should be sought on its removal.

Opaque paint layers and even stained varnish should be removed. This can be done with simple sanding. Alternatives for tough paints include water-based environmental friendly chemical paint strippers, or grit blasting using soft abrasives (such as walnut shells, dry ice or sodium bicarbonate).

Minor damages like holes should be patched to prevent further water ingress. Depending on the size, putty, wood epoxy and polyurethane fillers can be used before painting over.

Where large cavities due to termite damage or decay are found, partial or full replacement may be needed. The replaced section should be of similar timber specie and grain direction to the original.

All new replacement and existing timber should also be treated against termite and wet rot with appropriate biocide and preservatives.

Maintenance

- Compared to the timber structural frame, timber facades are lightweight infill layers that are designed to be replaced every 10-20 years. Nonetheless, maintenance inspection and repairs should be carried out periodically, so as to prevent the need for premature replacements.
- Any evidences of poor drainage, locations of potentially trapped moisture, etc., should be addressed. These include clearing of any blocked drains, gutters, and splits in the wood that can introduce dampness to any exposed timber surfaces.
- Regular checks should also be made on the condition of the paintwork or varnishes. Peeling and cracked paintworks should be removed and the timber repainted to protect against moisture ingress and ultra violet degradation. However, avoid repeatedly painting over the timber as the thickened layers of paint can instead obscure signs of decay underneath.

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

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Pages 18 (top left); 23 (all); 26 (all); 33 (all); 39 (left column, bottom left & middle); 44 (all); 54 (all); 55 (all); 58 (top left & middle left); 61 (left); 71 (bottom right); 72 (top); 84 (all)

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(Photography by Jeremy San or Randy Loh)
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Singapore Heritage Society and Estate of the late Jeremy San Tzer Ning
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Studio Lapis
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