Heritage Conservation as Green Development at the George Town World Heritage Site

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Abstract—George Town was inscribed as an UNESCO World Heritage Site in 2008. The conservation of heritage buildings is based on the principles of green development. The characteristic shophouses, built since the 1790s, used locally sourced and eco-friendly materials such as clay bricks, terracotta tiles and timber in designs suitable to the climate, culture and geology to create naturally cool interiors with low energy use. Modern materials such as cement, concrete, steel, glass and plastic consume more energy in their production, are poorly suited to the climate and geology, and pose threats to traditional-style buildings. Conserving the heritage buildings using traditional materials and conforming to the traditional deisgn principles minimises the contribution to global warming and the depletion of the earth's stock of natural materials.

Introduction

The city of George Town was established in 1786 by the British East India Company (EIC) on the north-east corner of Penang Island, along one of the most profitable trade routes in the 18th century. Its favourable location at the northern entryway to the Straits of Malacca, and sheltered from the monsoon winds, made the town a preferred port of call along the route. The town flourished as merchants from east and west converged in the town, bringing diverse yet distinct influences that shaped the built architecture and social fabric of the town that can still be seen today.

In 2008, George Town, along with the historic city of Malacca, was jointly inscribed as a UNESCO World Heritage Site (Figure 1). The recognition was based upon three Outstanding Universal Values, acknowledging both cities as multicultural trading towns; for their multicultural heritage and traditions; and the unique architecture, culture and townscape. A total area of 2.62 km^2 (262 hectares) of George Town was listed in the inscription, and it covered ninety-two streets and seven traditional jetties belonging to specific clans. The site also held 5,285 buildings, of which 3,890 units were pre- and post-war heritage shophouses, which had been designed to suit the geology and climate and which used materials close at hand for their construction.

Importance of heritage conservation

The Burra Charter, first published in 1979 by the Australian International Council on Monuments and Sites (ICOMOS) and revised in 2013, serves as an important guiding

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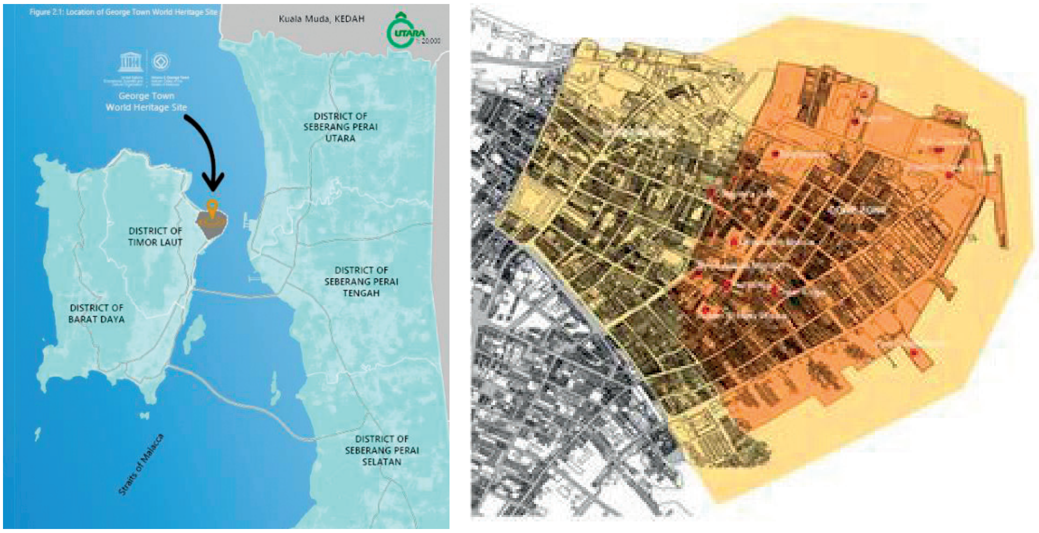

Figure 1. Map of George Town, Penang, indicating the UNESCO World Heritage Site Core Zone (dark orange) and Buffer Zone (light yellow). Source: Replacement SAP for George Town World Heritage Site

document that defined heritage conservation beyond tangible and physical forms, while providing standard guidelines for best practices in conserving built heritage around the globe. Article Two of the Charter mentioned the need to adopt a cautious approach in heritage conservation, changing as much as necessary but as little as possible. Article Four specified the importance of all heritage conservation efforts to employ all knowledge, skills and disciplines which can contribute to the study and care of the place.

Traditional techniques and material are preferred for the conservation of buildings in whole or in part, in order to retain the cultural significance of the building. In some circumstances, modern techniques and materials must be employed, when these alternatives offer substantial conservation benefits over traditional options. Therefore, conservation of heritage buildings, especially in multicultural fabrics and landscapes, can be built on the following principles: 1. maintain the original architectural form as much as possible; 2. maintain the original architectural structure as much as possible; 3. maintain the original material as much as possible; and 4. use the original technique as much as possible.

The Special Area Plan for George Town World Heritage Site (2016) further defined conservation for built heritage in the George Town World Heritage Site (GTWHS) as follows:

> Buildings to be conserved shall be retained, restored or preserved in accordance with this regulation. In the event that the original structural elements need to be repaired or replaced, their features shall be retained. Selective replacement may be considered only when absolutely necessary. Total reconstruction is totally and strictly prohibited. No building or structure shall be altered or demolished if there is any conceivable way of preserving it in its original or current condition. Adaptive reuse of heritage building is recommended and encouraged to generate new life to such buildings in line with the "Intelligent and Sustainable Heritage City" concept.
>
> When upgrading and adapting a building for new use, the existing structure

> should be retained by strengthening and repairing the structural elements. Any alteration or strengthening to structural elements should be done in the most sympathetic and unobtrusive way possible, using original methods and materials whenever possible, or if not, matching with materials of similar properties. If a building is deemed unsafe, it should be made safe, following original methods and materials.
>
> The preservation and conservation on activities on heritage assets and new compatible developments in the GTWHS shall need to adhere and be carried out to achieve the vision and conservation objectives as described.

There is a clear alignment and synergy in conservation principles, especially for built heritage, between the Special Area Plan and the Burra Charter, whereby the identity and integrity of the restored building, and its surrounding ecosystems, are maintained as close as possible to the original building. This applies to all buildings in GTWHS, shop or residence, but in particular to the shophouses that are threatened by redevelopment, dilapidation and climate change. Failure to uphold, apply and implement these principles will result in impending loss and demolition of both the built heritage as well as the social history of GTWHS.

Can heritage conservation be considered as green development?

The concept of development is often misconstrued as the need to replace existing old or vacant development opportunities with new, modern and technologically-advanced structures. For heritage city development, this is often perceived as the demolition of old and dilapidated buildings, only to be replaced by modern high rises that can accommodate more people per unit area of land. However, in Pearson (1992), development is described as an improvement — either qualitative, quantitative, or both — in the use of available resources. Urban and city planners have also adopted approaches that are more people-sensitive and context-specific, while abiding by limitations such as resource availability, capacity and skills, and the need to secure and de-risk heritage cities from impending threats of climate change. Development must be guided by principles of sustainability, whereby development meets the needs of the present without compromising the needs of the future.

Green development is commonly represented by images of environmentally-conscious designs, whereby buildings are developed to be energy and resource efficient, while reducing the environmental costs. Very often, green developments are associated with the use of modern solutions such as solar cells, LED lighting and effective waste water management. However, there is another element, namely the community and cultural sensitivities and values that should be taken into the guiding principles of green development.

While the concepts of heritage conservation and green development may appear to be two separate, non-interactive aspects for guiding urban redevelopment, there are many synergies in practice that makes these two concepts complementary. By drawing examples from heritage conservation of buildings in GTWHS, we can clearly see the overlaps in heritage conservation and green development, and how these interactions should be mainstreamed to further guide conservation efforts in other parts of Penang, as well as being adopted and adapted to other heritage-significant sites that share similar conditions.

Green heritage houses

Penang lies approximately 5 degrees north of the Equator, hence the climate is hot and humid throughout the entire year. In certain periods within a year, the weather can be extremely hot and dry, while other periods will see heavy rainfall and occasional inundation. These fluctuations have proved to be challenging for urban development in the past. As an island, Penang has a high underground water table, and this was both a challenge and an opportunity for builders in the past, as they had to build structures that were resilient to fluctuations in the water table, while using the evaporation effect to cool the houses naturally.

Many houses predate the introduction of electricity to Penang in 1905, hence these buildings were designed to optimise natural lighting and ventilation within the houses. Even after 1905, many of the newer buildings maintained the traditional layout and design of the houses, as electricity was not easily available and affordable. Many modern appliances such as electrical fans, lights and air conditioning units have replaced the use of fan lights, air wells and air vents, meaning the homes are less energy-efficient and have higher environmental costs. However, modern conservation efforts have seen conservation architects and designers seamlessly blend modern technology with traditional design, allowing them to restore heritage buildings to their original, less-costly and more energy-efficient homes.

Figure 2. Chinese temples and shophouses along King Street, Penang

The shophouse as an identity for George Town

Shophouses are unique architectural solutions to accommodate growing population, balanced with economic and social growth, commonly found in Penang and other regions of Southeast Asia, with variations also found as far away as South China and South Asia. There are six main shophouse styles in Penang, reflective of the different temporal and cultural influences throughout its development (Figure 2). The earliest shophouses were simple, low structures dating from the 1790s until the 1850s. Over time, the shophouses became grander and more elaborate, and adopted Western and Eastern styles. Many shophouses adopted the Southern Chinese Eclectic Style (1840s to 1900s), before evolving to the Early and Late Straits Eclectic Styles (1890s to 1940s), and the Art Deco (1930s to 1960s) and Modern Style (1950s to 1970s).

Figure 3. A cross-section of shophouses found in Penang. Source: *The Encyclopaedia of Malaysia Architecture*

Typically, shophouses are built facing a street or walkway, terraced with a load bearing wall between units, and low-rise, having only two to three storeys (Figure 3). These buildings are usually narrow and long, partly because taxes were levied based on the width of the façade, and partly because this layout accommodated more units on a limited plot of land. A row of shophouses may also share a common veranda, or five-foot way, that is open at all times as a continued walkway on the side of the streets (Figure 4). These five-foot ways, or *goh kha ki*, are distinctively Southeast Asian, adopted to mitigate the sun and rain in the tropics. Another distinctive characteristic of shophouses is that they use lime plaster on structural walls and pillars, allowing for underground water to travel from the ground to the surface via capillary effect, before evaporating and cooling the houses naturally.

These buildings are multifunctional, with the ground floor usually used as business or trade premises, while the upper floors are used for residential purposes. As these houses are long, air wells and courtyards are also incorporated to provide lighting and ventilation for the lower storey, as well as to break the units into several sections, separating the formal, business area from the informal, living area.

As with many buildings, the façade of the shophouse is supposed to showcase the

Figure 4. An example of five-foot way (left) along a row of shophouses, and an air well (right) in George Town. Source: Lim Gaik Siang

status and social standing of the owners and occupants of the unit. This is especially reflected in the later styles, especially the Straits Eclectic Styles in which the façade features ornate pillars ending with either Chinese or European pillar heads. The upper level of the façade also features three-dimensional decorative plaster walls heavily adorned with both Chinese and European decorations. While the decorative façade adds aesthetics to the street view, it also plays an important, functional role in keeping the shophouse energy-efficient and climate friendly (Figure 5).

At the lower level, heavy timber doors with intricate carvings are used to provide ventilation to the unit, without compromising on the security of the occupants and business within the unit. Windows flank either side of the main door, topped with fan lights to increase the flow of light and air into the house. Decorative air vents are also installed right above the fan lights to improve ventilation to the house. At the upper level, wooden louvre shutters and fan lights are installed across the façade wall to improve lighting and ventilation to the house, hence improving the quality of life in the absence of modern innovations such as lights, fans and air conditioners.

When viewed from a modern perspective, shophouses are ingenious solutions to mitigating urban sprawl, while providing ample opportunities for business and families to flourish. The design of living premises above business premises means better utilisation of space, and reduced need for commuting. The five-foot ways, first mandated by Sir Stamford Raffles for the Town Plan of Singapore in 1822, and then spreading across other Straits Settlements including Penang, encouraged the development of walking passages along the streets while discouraging the use of cars, which indirectly reduces

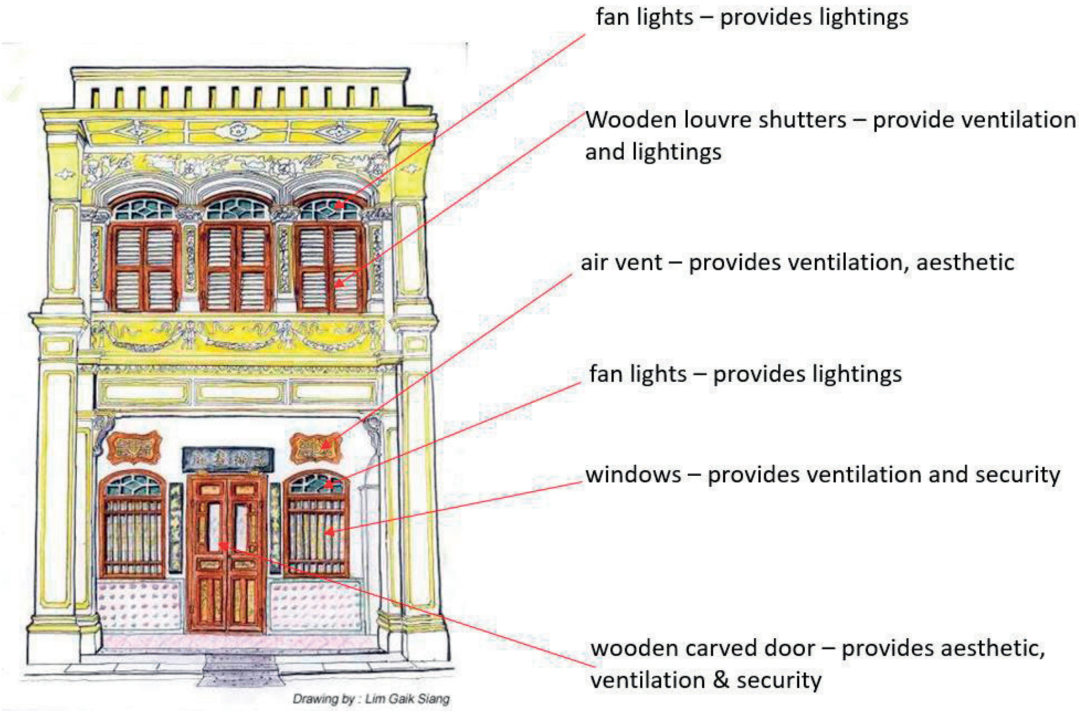

Figure 5. A typical façade of heritage shophouses found in George Town. Source: Lim Gaik Siang

emission of carbon monoxide, carbon dioxide and heat on the road and reduces ambient street temperature. The façade, while adding to the aesthetic value of the streetscape, is carefully designed to ensure that the shophouse is well lit and ventilated throughout the day. This solution can be readapted to the modern day setting as a means to reduce dependency on modern technology and innovation.

Sustainable materials for Penang shophouses

Although the shophouses in Penang can be categorised according to the time period and architectural style, they share many common materials used. These materials are very often sourced locally, in a sustainable manner, with very low carbon footprints.

Flooring

The floors of many shophouses in Penang are lined with the easily identified, red hued terracotta tiles. These tiles are made from a mixture of iron-rich clay with water, pressed and dried in the sun before they are baked in a kiln at a temperature of approximately 1300ºC. The high temperature is necessary to render the tile porous, a trait that is very advantageous in tropical houses, including the shophouses in Penang. The porous nature of the tiles allows moisture gathered from underground water to pass through the tiles to the surface, before it is evaporated or carried away by the wind. This process balances the underground hydrostatic pressure, due to tidal fluctuations and surrounding ecosystem changes, while the evaporation provides a cooling effect for the house.

Terracotta tiles are also highly durable, making it an ideal material for flooring. They are also naturally resistant to mould and bacteria as these tiles are alkaline in nature. Terracotta tiles are also fire resistant, as the base material is clay, and have a higher heat capacity as compared to other materials, making it a good insulator. This helps to protect homes from heating up during the day, and prevents rapid cooling of the ground during the night. Most of the terracotta tiles found in GTWHS are handmade from clay, a material that can be sourced sustainably without negatively impacting the surrounding ecology. Terracotta tiles are also inert, hence they do not release any hazardous chemicals or gases throughout the duration of their use.

Wall masonry: clay bricks

Shophouses marked a departure from traditional village or attap houses as the walls are built with clay bricks instead of wood or other traditional materials. Clay bricks have been widely used across the world. They were hand made up until 1825, when the brick making machine was invented to replace human labour. Clay bricks have been used extensively in buildings in GTWHS, as indicated by historical records. On Kelly's map from 1891-1893, there are detailed drawings showing the use of clay bricks for walls (Figure 6). Most of the bungalows and shophouses marked on the map were constructed with clay bricks. Most of the bricks used in Penang were sourced locally, and place-names such as Brick Kiln Road still record this legacy. Clay bricks are simply produced by mixing clay with water, before it is hardened under the sun or in kilns. The ratio of water to clay affects the density, durability as well as porosity of the bricks for usage in different parts of the house.

During the manufacturing process, clay is heated to a sintering process that causes the particles to fuse, resulting in clay bodies with strong, stable ceramic bonds. These strong bonds enable clay bricks to withstand severe weathering actions, and make them inert to almost all chemical reactions. These bonds also make the bricks highly durable, especially when exposed to severe temperature changes.

Figure 6. A section of Kelly's map (1891–1893) indicating clay brick structures in red ink. Source: JUPEM, Department of Survey and Mapping Malaysia

Clay bricks exhibit better thermal insulation properties as compared to other building materials such as concrete. The perforations within the brick structure create a vast capillary network that draws water and moisture away from the ground into the brick structure. As the water droplets have high heat capacity, they draw heat away from the surrounding, making it an ideal insulating material. The capillary effect promotes the 'breathability' of the walls, whereby salt and moisture travels from the ground to the surface of the brick, before it is evaporated or blown away, leaving a naturally cooling effect to the house.

Clay brick walls were favoured as a building material for shophouses in Penang also because of their ability to insulate against sound. Due to their thickness and density, the brick structure deadens noise transmission, muffling noise from the streets, neighbouring homes and other sources. Clay bricks are also fireproof and incombustible, making them ideal building materials. The use of bricks will not contribute to the start of rapid fire, and instead, has the ability to withstand and slow down the spread of fire, a common hazard in heritage cities. As clay bricks are made entirely of natural products, they can be crushed and returned to the soil to be repurposed for other use.

Wall masonry: lime plaster

Slaked lime has been used as a binder for lime concrete, lime, mortar and lime plaster for thousands of years, across various cultures, and is still in use today. This environmentally friendly material is made from naturally-occurring resources such as limestone or mollusc shells which are crushed, burnt and cooled before use. The burning in a kiln at 800ºC removes carbon dioxide from the material, which will be reabsorbed later. The slake lime is processed into mortar and applied onto clay tiles to secure the walls. The lime plaster reabsorbs atmospheric carbon dioxide to form calcium carbonate, resulting in a mortar matrix that is strong yet flexible, and less prone to cracking from weathering.

The high pH value of lime makes the mortar a natural fungicide, preventing mould and algae from growing on the walls. As lime plaster is permeable, it further promotes the 'breathability' of walls, as ground moisture drawn up through the capillary effects of clay bricks passes through the lime plaster before it evaporates. The use of lime plaster is still strongly advocated in heritage conservation practices as it is a more environmentally sensitive material compared to modern mortar and plaster alternatives.

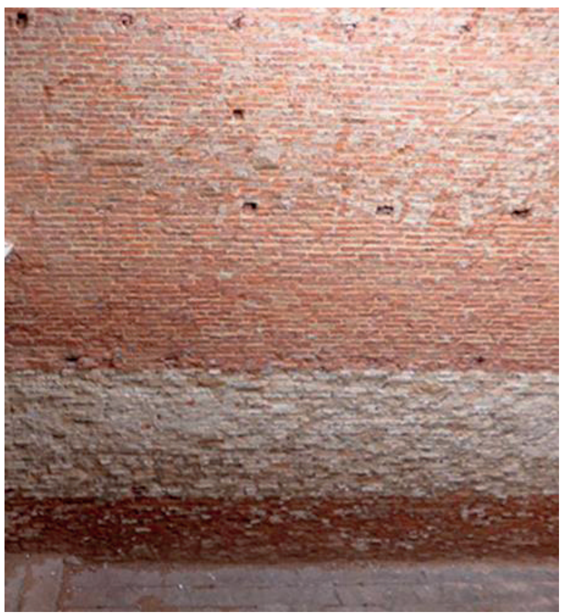

Figure 7. Exposed wall showing clay brick tiles in a shophouse in George Town. Source: Lim Gaik Siang

Finishing

Most of the walls of shophouses in Penang were traditionally finished with coats of lime wash for aesthetic value as well as many other environmentally sensitive properties. As the walls of Penang shophouses play an important role in underground

Figure 8. Stonemasons using lime plaster to repair an exterior wall in George Town. Source: Lim Gaik Siang

Figure 9. Terracotta clay U or V tiles on the roofscape of George Town. Source: Gwynn Jenkins and Tan Yeow Wooi, *Introduction to Heritage Building Materials*.

hydrostatic regulation, it is vital that all materials chosen are permeable or breathable. This applies even for the finishing, hence lime wash was used. The use of other types of paint, especially synthetic paint, prevents trapped moisture from escaping into the atmosphere, resulting in unsightly build ups, bubbles and cracks that will further compromise the structure.

Lime wash can be obtained by thinning aged lime putty with water before it is applied on walls (Figure 8). Certain natural pigments including ochre and indigo are added to the lime wash before it is applied on the walls, allowing for the buildings or walls to stand out aesthetically. As the pigment tone changes in relation to moisture content of the wall, it lends a layer of depth and luminosity to otherwise flat walls.

Traditional lime wash is environmentally friendly, as the source materials are natural lime and natural pigments, and free of chemical solvents. Lime wash has high pH value, resulting in a highly alkaline environment which inhibits the growth of mould and bacteria. As lime wash is made from natural products, it contains no volatile organic compounds, and hence is odourless and non-toxic.

Roof tiles

Most of the roof tiles used for Penang shophouses are terracotta. They share similar properties to the terracotta tiles used for flooring, and gives the distinctive red roof-scape across the city. Terracotta tiles are chosen for their high durability and ability to withstand severe weather changes, especially from direct sunshine. The ability to insulate heat makes it an ideal material for roofing, as it prevents the interior of the house from heating up. As terracotta is also slightly porous, the roof tiles allow for hot air to rise and pass through the tiles, before it is disbursed into the atmosphere.

In the GTWHS, the roof tiles are made to shape like a V, and laid in specific manner to allow for rain to flow downwards smoothly without compromising the structure of the house (Figure 9). Similarly, the overlapping laying method creates small voids between the tiles, allowing for air to be trapped in these voids, hence enhancing the insulating effect of the roof.

Wooden and timber structures

Wooden and timber materials were still very much preferred in the design and building of shophouses in Penang, but instead of serving as the main construction material, they are now used to furnish and fit the house accordingly. Solid timber such as teak, merbau and belian (or Bornean ironwood) are sourced from neighbouring states and processed into various fittings such as doors, staircases, flooring and windows. Timber and wooden materials are also chosen because they are durable, able to absorb vibration and heat, and can be easily painted over to improve the aesthetic quality of the wood.

Many shophouses in Penang still sport intricately carved, double-leaved wooden doors at the front of the house (Figure 10). These wooden doors are carved with auspicious designs to bring blessings to the occupants, but also serve as an important barrier to prevent the outside world peeking into the inner workings of the home. Some doors are designed to have movable vents in the middle to allow for air to flow into the house when the doors are closed, without compromising the security or the privacy of the household.

A pair of timber-panelled windows usually flank the front door, and they are topped with fan lights. These windows and fan lights allow air and light into the house. The iron grill design also allows for better security

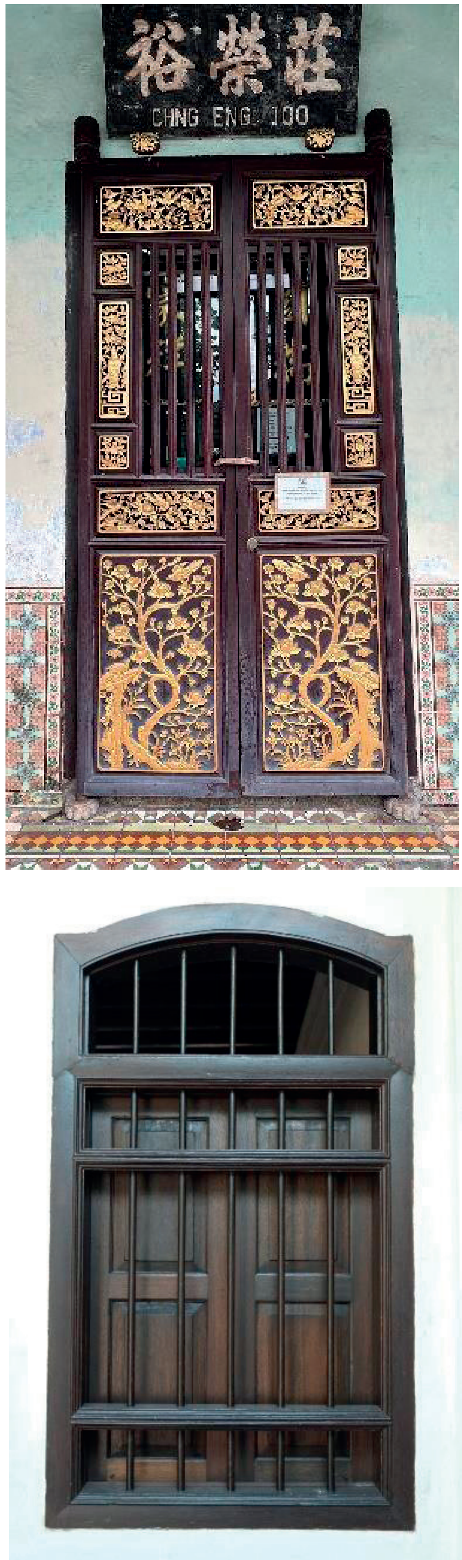

Figure 10. Carved wooden door (top) and window structure (bottom) commonly seen in shophouses across George Town. Source: Lim Gaik Siang

and privacy, while still allowing air to flow into the house. Similarly, wooden louvre shuttered windows are installed on the upper levels of the shophouses, allowing light and air to flow into the upper levels of the house.

At the top of the façade, a pair of air vents are installed on either side, just above the fan lights. These wooden, carved air vents, usually bearing auspicious symbols for prosperity or longevity, allow for constant air flow into the house, hence cross ventilating the house, even when all the doors and windows are closed.

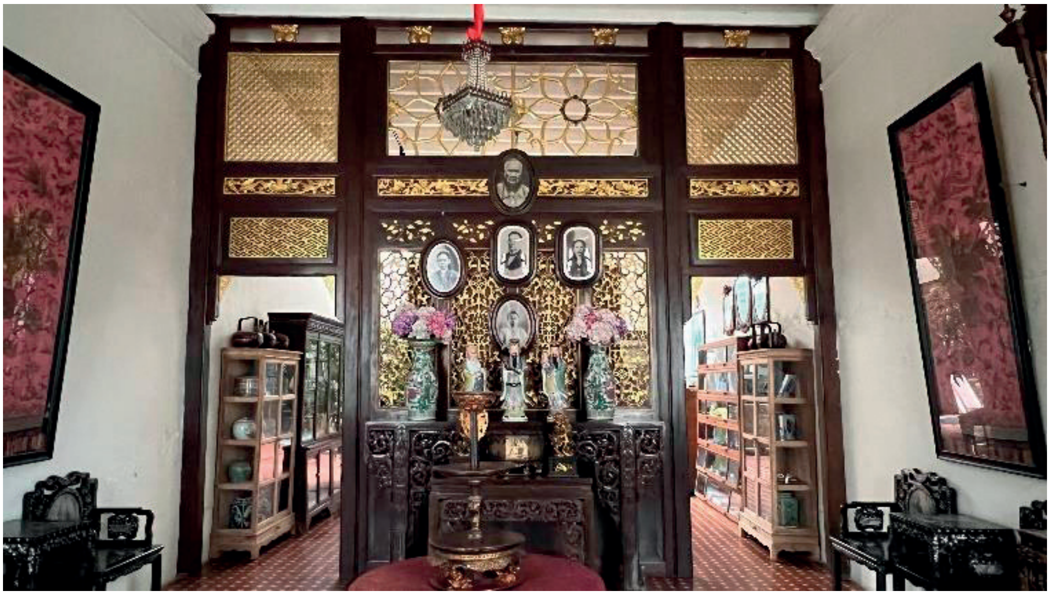

Figure 11. An elaborately carved wooden screen separating two sections of the shophouse. Source: Lim Gaik Siang

In some shophouses, a big, wooden partition screen is installed to separate the business area from the living area, which lies further inside the long house (Figure 11). The wooden screen prevents patrons and traders working at the front of the house from peeking into the back of the house. These screens are also carved or inlaid to allow air and light to flow from the front of the house to the further reaches inside the house.

Timber floorboards are often used for the flooring of the upper levels of the shophouses. These floorboards are preferred as they are lighter in comparison to other materials, highly durable and can withstand strong vibrations. Wooden floorboards are also chosen because they can expand and contract with changes in temperature, and the flexibility will not compromise the stability of the upper levels. The tiny gaps in between the floorboards also allow for hot air to rise upwards and away from the house, allowing for cool air to naturally ventilate the house.

Timber is also used for the staircase and its fittings, including handrails and balustrades. The flexible nature of wood absorbs the impact and vibration of occupants moving up and down the stairs. The wooden staircases are also lighter and more easily installed compared to other materials. However, the first three steps from the bottom are always replaced with granite for better stability and anchorage.

Granite air well

Air wells are another distinct feature in shophouses across GTWHS (Figure 12). As these shophouses are long and narrow, one or more air wells are installed in suitable breaks along the house, opening up the house for better ventilation and lighting. These air wells are fitted with granite slabs at a lower level, and completed with drains leading to and away from the air well (Figure 13). When it is dry, the air well serves as an open courtyard and common area for members of the household to gather and socialise. When it rains, water is directed from the roof, through the gutters, to the air well before it is directed outwards and away from the house. The temporary pooling of water at the air well reduces the immediate run-off into nearby drains, hence reducing the risk of overloading the drains and flooding. This is particularly important as most shophouses open onto the street, and floods will affect the frontage and business area of the house.

Figure 12. An air well, or open courtyard, in a shophouse in George Town, featuring granite slabs embedded in a recess to collect water. Source: Lim Gaik Siang

The careful selection of materials such as clay bricks, terracotta tiles and lime plaster shows that traditional designers and architects place emphasis on using locally-sourced materials that are better adapted to local culture and climate, as opposed to using materials that are non-sustainable and with higher energy cost. However, the lack of awareness and knowledge of these natural designs has resulted in modern buildings that are less energy-efficient and that add to the urban heat island effect in the city. There is an urgent need to adopt heritage-sensitive policies in restoration, adaptive reuse and brownfield development in the city to conserve the integrity and identity of these heritage houses, while indirectly mitigating the impact of climate change within the city.

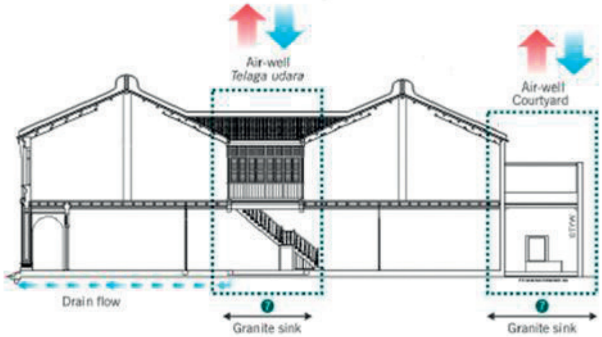

Figure 13. A cross-section diagram showing the flow of water into the house, through the granite air well, and out to the common drain. Source: Gwynn Jenkins and Tan Yeow Wooi, *Introduction to Heritage Building Materials*.

Unsympathetic developments are not fit for heritage cities

There is a need to redevelop heritage cities like GTWHS to be livable and functional, while preserving the historic diversity of the city. Heritage redevelopment and regeneration need to be guided by principles that respect the *genius loci*, and be sympathetic to the original use and structure of the building. The construction of new buildings on vacant land or replacing dilapidated buildings will increase the energy and emission footprint of the city. Selection of modern materials may not always be compatible with the existing ecology, and should be strongly discouraged in both new developments and for conservation projects. Below are some examples of materials and methods employed for new developments which are unsympathetic to the ecology of heritage cities such as GTWHS.

Piling

As modern materials tend to be heavier than traditional building materials, there is a need to stabilise the soil and ground before construction can take place. In GTWHS, parts of the city sit on sandy soil while other parts were previously swamps. Very often, piles are hammered into the ground to provide for solid foundation before the buildings are erected on these foundation pillars. However, modern piling methods disrupt the underground hydrostatic pressure, and displace the water to surrounding structures. The use of concrete piles, which are non-permeable, blocks underground water from flowing, and forces the water to find other channels. This leads to increased pressure in traditional heritage houses near the development site, resulting in possible damage including seepage, settlement and cracking, and erosion.

Waterproofing

In modern buildings, barriers are created to prevent water from passing through surfaces such as foundation pillars, walls and roofs. While this is useful to prevent rainwater from entering the home, it further disrupts the underground hydrostatic pressure. The capillary effect formed by using clay bricks and terracotta tiles is greatly reduced, and underground water has no means to reach the surface and evaporate. The change in hydrological balance possibly increases the flow and pressure underground, leading to possible cases of erosion and collapse. The rapid movement of underground water also disrupts the stability of the buildings, leading to potential cracking and collapse of walls and other structures.

The selection of construction materials also affects the fragile ecosystems surrounding heritage buildings, including the many shophouses found in GTWHS. While these modern materials are preferred for modern development, they are not compatible for heritage conservation purposes, and are less ecologically friendly than traditional materials.

Concrete and cement

Concrete forms the backbone of modern architecture. Concrete is made with cement, sand and water, mixed in a fixed ratio, to form bonded aggregates for mortar

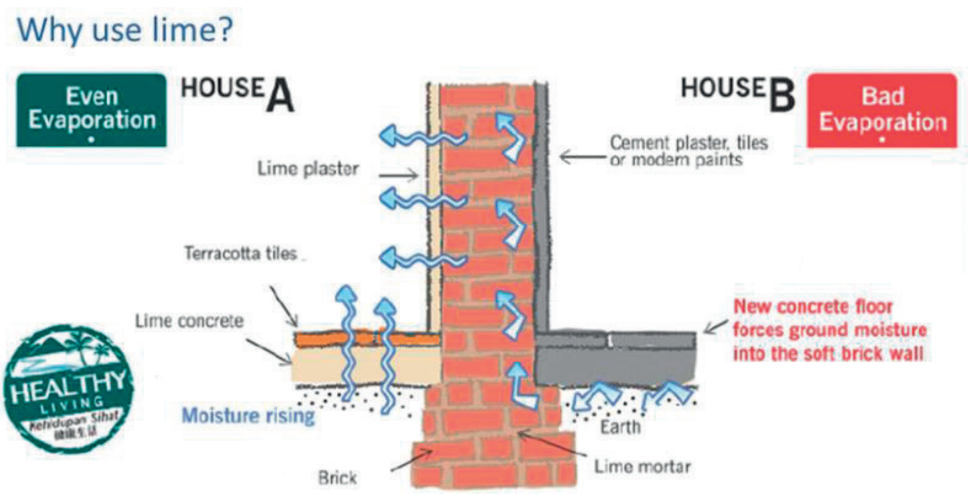

Figure 14. Diagram showing the displacement of underground water to surrounding houses due to the use of unsuitable materials such as concrete and cement. Source: Gwynn Jenkins and Tan Yeow Wooi, *Introduction to Heritage Materials.*

and plaster. The use of concrete had replaced the use of lime plaster, but there are many disadvantages when used in a heritage setting. Concrete is generally heavier than lime mortar, and has lower tensile strength in comparison to other materials, with a higher tendency to crack. It is less malleable than other types of mortar, and has lower seismic load. Very often, it needs to be reinforced with iron bars or other materials to increase the ability to withstand a heavy load. Concrete may contain soluble salts which can effloresce and cause damage to the surrounding structures and buildings. It also has the tendency to shrink over time, due to the loss of absorbed water, rendering the structure fragile and brittle.

Cement is one of the most important building materials for modern construction, as it acts as a binding agent for stones, bricks, or tiles. Cement is a very fine powdery substance chiefly made up of limestone (calcium), sand or clay (silicon), bauxite (aluminum), and iron ore, and may include shells, chalk, marl, shale, clay, blast furnace slag, and slate. The raw ingredients are processed in cement manufacturing plants where they are heated to form a rock-hard substance, which is then ground into a fine powder to be sold.

Cement is an integral part of the urban infrastructure. It is used to make concrete as well as mortar, and to secure the infrastructure by binding the building blocks. When mixed with water, cement undergoes a chemical reaction and forms a paste that sets and hardens to bind individual structures of building materials.

Concrete is made of cement, water, sand, and gravel mixed in definite proportions, whereas mortar consists of cement, water, and lime aggregate. These are both used to bind rocks, stones, bricks, and other building units, to fill or seal any gaps, and to make decorative patterns. Cement mixed with water silicates and aluminates makes a water-repellant hardened mass that is used for waterproofing structures and walls. However, there are also significant disadvantages when using cement.

Cement is generally not environmentally friendly. To produce cement, materials such as limestone, clay, and chalk are extracted from natural resources and burnt to produce an ash-like substance. The production of cement is energy and resource intensive, and releases a lot of carbon dioxide into the atmosphere, where it remains for the rest of its life, while lime absorbs carbon dioxide for the rest of its life. While cement is a preferred binding agent, it is not able to withstand heavy loads, and often needs to be mixed with other materials to reinforce its strength and durability. Cement is also chemically unstable, and will disintegrate easily when in contact with alkaline-based or sulfate-based substances. Cement is also non-permeable, hence underground water travelling up through the walls cannot pass through cement. This will then displace the underground hydrostatic pressure to the surrounding buildings, increasing the hydrological load of those buildings, and in the long run, will compromise the structure.

Figure 15. The use of glass as an exterior wall in a modern building along Penang Street, Penang, altering the traditional ecosystem of the area. Source: Lim Gaik Siang

Steel and glass

Steel has been commonly used in new buildings to replace timber as beams, pillars, battens, and purlins. Steel is very heavy and rigid, and is not malleable to accommodate heavy load and impact. The heavy weight of steel, combined with other heavy materials such as concrete and cement, requires strong foundations to support such building through the use of underground piling.

As steel is rigid, it does not absorb vibration easily. When there are strong vibrations, buildings loaded by steel structures will crack easily. If it is a development where the new building is sharing a load-bearing wall with another heritage building, then it will affect the heritage buildings.

The use of glass has been gaining popularity for modern buildings, as it is used to replace walls, doors, windows or partitions (Figure 15). While the use of glass gives the building a modern look, it does not provide good insulation from the heat of the sun. The use of glass in buildings has increased the use of air-conditioners, as the air-cooling system is required to remove the latent heat from the building, hence increasing the energy cost of the building.

There are several other disadvantages in using glass as a building material for heritage conservation. The manufacturing of glass is energy intensive, and as there are no recycling facilities available for glass in the country, it cannot be crushed or ground for reuse. Glass is also highly brittle, and the rigidity of glass makes it weak against impact or shocks. Strong vibrations or impact will shatter glass easily, leaving broken pieces that may be harmful to people and the environment. The use of glass as the exterior of buildings increases glare and heat deflection into the streets, hence raising the ambient temperature of the ecosystem, contributing to the urban heat island effect.

Plastic

In recent years, plastics have been used extensively in the construction industry. Plastics have the advantage of being lighter in weight, easily malleable, durable and able to withstand strong shocks and vibrations. Materials such as polyethylene and PVC are widely used to manufacture flooring as they are light, easily assembled, easily cleaned and easy to replace when damaged. Certain forms of plastics such as olefin or vinyl have been used for roofing as they can withstand high temperatures without changing their composition or their ability to repel water. Polyurethane has also been used as doors, window frames and in-wall filling as it is light, and able to provide insulation against temperature fluctuations.

Despite the many varieties and possible uses of plastics in modern construction, they are not suitable for heritage homes, including shophouses in GTHWS. Plastics are sourced from hydrocarbons such as crude oil and coal, and these natural resources are fast depleting. The mining of crude oil is also one of the leading causes of global warming and climate change, and there have been numerous calls globally to decarbonise our industries, essentially stopping the use of crude oil and gas and their associated products in modern day living. Most plastics are single-use plastics, and cannot be reused or recycled to form other materials. They take a long time to degrade, and in the process, release significant amounts of greenhouse gases into the environment. Plastics are therefore not a green and development-friendly solution for heritage conservation. Plastics are also non-permeable, and when used in construction and restoration of heritage houses may disrupt the natural hydrostatic pressure and water ecosystem of the building, leading to long-term defects and damages.

Conclusion

In conclusion, when new buildings are built, new construction materials are used, and these have a huge impact on the environment, such as their contribution to global warming, their use of energy and their depletion of natural resources.

Accelerating global warming

The use of new materials makes the building hotter, so air-conditioning is required. When air-conditioning is used, the ambient temperature of the environment increases, leading to intensified use of air-conditioning systems. This negative feedback cycle (Figure 16) is hard to break, and will lead to more significant environmental impacts such as urban heat island effects, and degradation of microbiological ecosystems in urban areas.

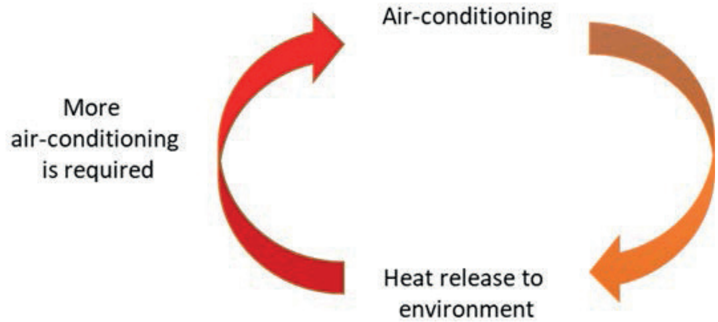

Figure 16. A negative feedback loop showing the cycle of heat disbursement and demand for air-conditioning in modern setting. Source: Lim Gaik Siang

Studies have shown that some refrigerants deplete the ozone layer, leading to an increase in the amount of type B ultra violet light (UVB) that reaches the earth's surface. Laboratory and epidemiological studies demonstrate that UVB is a threat to human health and well-being, such as non-melanoma skin cancer, and plays a major role in malignant melanoma development. In addition, UVB has been linked to the development of cataracts, a clouding of the eye's lens.

Using more energy and mineral resources

Production of new building materials is energy-intensive, has higher energy cost compared to traditional alternatives, and requires the use of non-renewable resources, such as crude oil, and in the long run will lead to depletion of these resources.

In conclusion, by restoring a heritage building, we help to save the environment because the materials are recycled. At the same time, due to the original design and use of material, the heritage buildings are naturally cooler and do not need to have air-conditioning. This also helps to reduce global warming. In addition, the materials used in heritage buildings are "organic" and do not harm the environment. We must consider heritage conservation as part of green development. We should conserve existing heritage buildings in the process of development instead of pulling them down and building new structures.

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