Urban salinity and cultural heritage

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Urban salinity as a threat to cultural heritage places
A primer on the processes and effects of chloridation
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SUGGESTED COURSE OF ACTION

While the desirable course of action depends on the individual situation some general observations can be made. It is necessary to:

• inspect all heritage sites deemed to be aesthetically, culturally, socially or historically significant, whether they are (already) listed on the Local Environmental Plan or not;

• assess the presence and state of repair of a damp proof course;

• identify all those cultural heritage sites at risk from moisture ingress;

• assess the susceptibility of established gardens (plants) to increased salinisation of the soil; and

• develop conservation plans for all sites deemed at risk.

While in many instances the direct salinity impact on sites may not eventuate for some years, it is necessary to develop appropriate action strategies now. Once salt has become embedded in the building fabric, its removal will be much more complicated than the prevention of its occurrence. Also, while it is technically feasible to desalinate a building, this process is very time consuming and thus will cost many times more than the repair or initial installation of a damp proof course.

Prevention is better than Treatment ... and it is cheaper too!

A list of references and resources for further reading can be obtained from the author.

Modern backing wall for a sun dial erected from secondary bricks. Note that rising damp from the fountain basin has wetted the entire wall. The use of Portland cement exacerbated the effects of rising damp and cryptoflorescence. This wall exemplifies the dangers of inappropriate mixing of construction materials. Pioneer Settlement, Swan Hill (Photo by the author 1995).
WHAT IS THE THREAT?

High urban watertables, whether caused by rising ground water tables or by sewer and water pipe leakage, bring a continual supply of moisture close to the foundations of heritage structures.

It needs to be appreciated that many cultural resources are comprised of various constituent materials which may have different hygroscopic indices. For example, hygroscopic (moisture dependent) swelling and shrinking is a common phenomenon of all clay—derived products, such as pottery and bricks. Their hygroscopic indices, depending on the temperature at which the bricks were fired, differ from that of the mortar and any wooden components, such as window frames, beams etc. used in a building. Thus the materials swell or shrink at different rates, leading to increased differential mechanical stresses, gradual material fatigue and thus decay of the structure as a whole or its components.

Along with this moisture soluble salts are carried to or near the surface, and it is these salts that create major problems.

As a result, the historic environment of the Riverina is threatened by salt decay.

Unless action is taken to assess the magnitude of the potential problem for each of the towns in the Riverina, unless all historic structures in these towns are investigated to assess their significance to the town overall, as well as their susceptibility to urban salinity, and unless mitigative action is taken, salt decay will damage many structures, some beyond repair. Even where possible, the repair of these may be much more expensive than preventative action.

This decay may lead to the loss of many historic places and thus may change the appearance of the historic town centres as we know them.
WETTING OF STRUCTURES

The walling of stone and brick structures is subject to a variety of decay processes, most commonly the ingress of moisture into the fabric. Most frequent are rising damp, where ground moisture is drawn into the masonry surfaces and the mortar bonds by capillary action; falling damp, where leaking roofs, gutters and down pipes provide water flowing down a masonry surface and penetrating it due to gravity action; and penetrating damp, where cracks in the masonry surface, the renders or the mortar bonds allow ingress of moisture either from dew deposition or because of wind pressure. The extent of the damp is determined by the hygroscopic indices of the constituent materials, the availability of moisture and the degree of evaporation.

A damp-proof course, a layer of water-impermeable stone or other material introduced between the foundation and the walling, provides a barrier and thus prevents moisture intruding into the wall by capillary action. Damp-proof courses (DPC; synonyms: dry course, slate course) were traditionally made of slate, but tar, bitumen and (today) plastic lining are also used.

While a DPC can decay in its own right, for example due to chemical decomposition, it more commonly fails because of mechanical factors, such as differential settling of the foundations. It may also be absent altogether (in some older buildings) or partially deleted by alterations to the structure. By far the most common cause of moisture ingress, however, is that the DPC has been bypassed. Overzealous gardening and the application of large quantities of mulch and tan bark can lead to an accumulation of materials touching the walls and thus provide a conduit for moisture, as are new renders, new internal floors, or new and raised paved paths next to an existing structure.

However, small artefacts are usually so thin that the stresses created by the expansion of the salt can cause artefacts to break up. The artefactual material is at risk mainly during the initial moistening phase, when the ground is not yet perpetually waterlogged and the moisture levels in the ground are subject to fluctuations. Once the item has been removed from the saline environment and is allowed to dry, the salts will expand and cause the object to flake, eventually destroying it. Chloridation of pottery recovered from marine sites is a good example.

Pottery

There is a wide range of pottery in the European material culture in Australia, ranging from low-fired irdenware to hard-fired, very homogeneous porcelain. The latter is very much evidence of the economically better off. Since porcelain is impermeable to moisture it will last in immersion in saline or even marine waters, while normal pottery decays in a similar way to bricks.

Quartz artefacts

The bulk of the artefactual material in the Aboriginal sites in the southern Riverina is comprised of quartz tools. The impact of saline moisture on quartz is similar to that of quartz temper in bricks. Therefore, quartz implements in the ground are likely to be increasingly fractured and become unrecognisable.

Metals

Metals decay by oxidisation (‘corrode’) when three conditions are met: (i) the presence of an anode and a cathode; (ii) the presence of an electrolyte; and (iii) a metallic circuit which connects the anode and the cathode. Traditionally metals corrode slowly in the historical archaeological deposits of the Riverina, as moisture is only partially present, depending on precipitation, and as there have been only few salts which can create a solution. With the rising ground water table both conditions
A good example of differential decay caused by rising damp can be seen at the older (1930s) kiln at Mills Brickworks in Wagga Wagga. Here the entire foundation of the kiln has severe rising damp problems causing the decay of fabric. The bricks above the fire openings of the kiln, however, have been repeatedly exposed to increased heat causing their surfaces to harden and to shift the hygroscopic index of these bricks to such a degree that they are no longer susceptible to rising damp (Mills Brickworks, Wagga Wagga. Photo by the author 1996).

Concrete

Concrete has been used in construction since the 1840s but because it is still the main construction material, concrete structures in Australia have the public image of being ‘new’. Because of this concrete structures are often considered less significant by many in the wider heritage community and certainly by the general public. In addition, most concrete structures are public infrastructure developments, such as bridges, concrete grain silos, water towers, dams and drainage/irrigation channels, which are not imbued with any nostalgia-derived values in the public at large, but are representative of the agricultural expansion of the Riverina.

Concrete made from Portland cement is susceptible to salt attack. In addition to the physical stresses set up by the chlorides, which have been
If the water attracted by capillary action also contains salts in solution, this salt solution will also be deposited on the surfaces of the pore spaces. Once again, when the temperature of the air increases the masonry surface will dry off and the pore space will dry out, with the exception of the interface with the capillary rise. As the air dries out, the evaporation alone will cause salt crystals to attach to various places in the pore space.

As in the case of normal pore spaces and external moisture, during the next wetting cycle the salts will attract additional moisture and will create ever larger (and more) crystals. At every condensation event some of the salts will go back into solution and disperse, while other salts will be added in the next phase of wetting. If the condensation event results only in partial dissolution of existing crystals they are likely to grow at a faster rate. Once the pore has been filled with salt crystals thus created they will colonise the mouth of the pore and from there spread onto the masonry surface.

Stone

Fretting of stone is less common than fretting of brick, but nonetheless occurs frequently in sandstone and carbonate rock (eg. limestone). Clay minerals often present in the matrix of sandstones and carbonate rock make these rock types more prone to moisture effects; shrinking and swelling of these clay particles sets up internal stresses which fissure and rupture the rock, allowing further ingress of moisture. The main characteristic of these rock types is their porosity and their relative pore size, both of which vary from variety to variety.

Simplified model of chloridation effects on quartz tempers in brick (1). Quartz fragments are mixed in with the clay to temper the brick and to prevent cracking when the clay is shrinking during the drying process (2). When fired the heat forces out water from the crystal structure as well as the fissures in the quartz, expanding the quartz block. As the quartz block is tied into a hardened clay matrix the expansion of the quartz is constrained setting up internal stresses (3). Over time these stresses can cause fissures to develop that reach the outer surface of the brick and come into contact with the atmosphere (4) allowing ingress of moisture and salts in solution (5). The moisture can migrate in the fissures of the quartz as well as between the quartz and the fired clay. Growth and expansion of the salt crystals.
enhances the extant stresses causing the brick to fail (6).

Brick

Bricks, hygroscopic by nature, take up moisture if exposed to continuous access to such. Rising damp is a prime example of this phenomenon. The water is moved vertically and horizontally through the brickwork by capillary action of the mortar and then taken up by the bricks. The efficiency of (or damage caused by) capillary action is determined by the porosity of the material (the finer the pores the greater the capillary rise at an exponential rate) and the rate of evaporation (the less evaporation the greater the rise). The bricks are exposed to a wet-dry-cycle, with the central parts of the bricks acting as ventilators. Bricks made with unwashed beach sand as a temper material would contain substantial amounts of salts which would gradually seep to the surface and crystallise out. The capillary action also moves soluble salts into the brickwork, which if saturated can crystallise out on the surface of the bricks (efflorescence) as well as in their pores and cavities (cryptoflorescence). As salt crystallisation concurs with an expansion, the bricks are placed under internal stresses opening hairline fissures for further cryptoflorescence events.

Radial cracking of a brick which had been submerged for prolonged periods in 8-10 m depth of water in Lake Hume. The fissures radiate out from a piece of quartz temper which expanded during the firing process and set up internal stresses in the brick. The immersion in water weakened the bond of the clay minerals in the brick and allowed the cracks to develop. As the brick rested in a group of other bricks and rubble on the lake bed any mechanical impact can be excluded. Former settlement of Bowna, Lake Hume, near Albury. (Photo by the author 1995).
If some salts are present in the air, then these salts in solution will also be deposited on the masonry surface and the pore spaces. As the air dries out, these salts will form salt crystals. During the next wetting cycle the salts will attract additional moisture and will return wholly or partially into solution. As some of the attracted moisture will carry salts in solution, these total deposition of salts will increase, creating ever larger (and more) crystals.

The key parameters for capillary action is the porosity and the relative pore size of the material. It has been observed that the capillary head in masonry is greater if chloridation effects are present than in ‘normal’ rising damp situations. The hygroscopic nature of the salts attracts moisture from neighbouring crystals and thus carries the water further, in effect handing it on from crystal to crystal.

Example of chloridation of masonry caused by rising damp with capillary moisture penetration due to a broken damp-proof course. Note the gradual decrease of efflorescence at the chimney. The extent of rising damp is shown by mortar loss at the upper part. The broad coverage of the chloridation effect suggests a fluctuating ground water table. Rear of a fireplace, Murray Downs Homestead, Swan Hill. (Photo by the author 1994).

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In addition to the decay of the structural elements of heritage places we need to consider the changes in the setting of these sites. Heritage buildings can only rarely be seen in isolation as they form part of cultural landscapes, either of rural aspects, such as vineyards, orchards and field systems, or of urban areas. The latter can range from fully landscaped gardens to the purposive planting of food and utility tress around homesteads, from botanical gardens to street tree plantings. In addition, herbal gardens for medicinal purposes need to be considered. In these situations the ‘normal’ impact of salinisation on the viability of individual plants comes into play. Depending on the salt tolerance of the plant species some or all may dwarf or die off, effects which will demonstrably alter and thus most likely diminish the character of the place.

LANDSCAPED GARDENS

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ARCHAEOLOGICAL SITES

Chloridation effects are not confined to structures but affect archaeological sites and deposits as well. In general, all porous materials in contact with soil moisture are susceptible to salt attack. Unlike structures,
An example of a working damp proof course. Here the rising damp is halted by the damp proof course. While the masonry below exhibits very severe decay, both in the form of mortar loss and fretting of the brickwork, the masonry above the bitumen layer is unblemished. Unfortunately the bottom section has not seen any maintenance for a considerable period of time which, if left unchecked, would endanger the structural strength of the wall—which in turn might lead to a cracking of the damp proof course. (Rushworth, Vic.; Photo by the author 1995).

CHLORIDATION EFFECTS

Chloridation is a process which normally occurs near the sea or ocean. Sodium chloride, suspended in the air by wave action (esp. breakers), is deposited on the surface of materials by moist winds. Page 4 shows a model of moisture ingress into a pore space in masonry. At the top of the pore, air is exchanged with the outside atmosphere, while the bottom of the pore is filled with water brought there by capillary action. Moisture will not only condense at the surface of the masonry but will enter the cooler airspace in the pore, also condensing there. When the temperature of the air increases the masonry surface will dry off and the pore space will dry out, with the exception of the interface with the capillary rise. Depending on the moisture differential between the pore and the ambient air there can be an increased evaporation at the capillary interface resulting in the flow of moist air out of the pore.