TECHNICAL GUIDE

Salt attack and rising damp

A guide to salt damp in historic and older buildings

David Young for Heritage Council of NSW · Heritage Victoria · South Australian Department for Environment and Heritage · Adelaide City Council

Cover photographs

Left: Rendering the base of walls in a hard cement render is a very common, but poor treatment. The damp simply rises in the masonry behind and comes out above the render, which in this case has already been extended once. Maitland, NSW.

Centre: A boundary wall of rubble limestone in Gawler, SA, showing extensive loss of stone and mortar due to salt attack and rising damp. Damage such as this can be made worse if there is a watered garden on the other side of the wall. Salt from inorganic fertilisers will add to the decay.

Right: A house wall in suburban Melbourne with the tar and sand damp-proof course showing as the dark line above the third course of bricks. Although the walls may be dry above, there is now a need for maintenance of the mortar joints below the damp-proof course. They should be repointed in a weak lime and sand mix to control salt attack and so protect the surrounding bricks while also re-instating the structural integrity of the wall.

Authorship

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Understanding salt attack and rising damp

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1 Introduction

This guide aims to provide owners, consultants and contractors with sufficient information to understand what causes salt attack and rising damp (and also falling and penetrating damp) and to diagnose and identify appropriate repairs for cases commonly seen in Australia. While emphasis is given to buildings of heritage value, the principles apply to all older buildings.

Salt attack and rising damp are two separate but interrelated processes; both must be understood if damage is to be minimised and if corrective measures are to be successful. While the term rising damp has been commonly used to cover both aspects, it tends to overlook the role of salt, an issue that will become increasingly important as our buildings get older and as our soils become more saline.

Salt damp is a term widely used in South Australia to refer to high salt concentrations associated with rising damp. The term is quite apt, as it combines the two concepts of salt attack and rising damp. Though less an issue in some parts, the problem of high salt concentrations affects buildings across much of Australia, and so the term salt damp has begun to be used in other States. Salt damp is used throughout this guide to mean the combination of salt attack and rising damp.

This guide is divided into two parts: Part One (Sections 1–9) covers some background and provides an understanding of how salt attack and rising damp damage buildings, while Part Two (Sections 10–25) deals with diagnosis, maintenance and repair.

Those with insufficient time should at least read the next section (The Basics) which includes a summary of the Seven Key Steps needed to manage a salt damp problem. It also has some common Questions and Answers and important Dos and Don'ts.

Technical terms are explained in a glossary at the rear and there is a bibliography for further reading. Boxes containing illustrations or discussion of particular issues are distributed through the guide.

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The approach recommended by this guide is to treat a salt damp problem as one requiring thorough understanding of the causes, as well as ongoing attention if it is to be managed successfully. Approaching salt damp as a simple question of which damp-proofing technique should be employed, is neither the right question, nor is it likely to lead to a good outcome. There are many buildings with mild cases of salt damp which need attention, but which do not warrant insertion of a damp-proof course (DPC), at least in the short to medium term. This guide outlines a structured approach to salt damp problems so that appropriate methods and level of repair can be identified. This often enables retention of original fabric to be maximised and therefore heritage value to be retained.

2 The basics

Figure 1 The dense bluestone base courses of this Melbourne building help reduce upward movement of moisture. Dense stones such as bluestones and granites are commonly seen as base courses around Australia.

Figure 2 Typical salt damp damage in Adelaide, with decay of the bricks extending from about 0.5 to 1.2 metres above ground. There are no obvious signs of salt because it has been washed off by rain. Paler (underfired) bricks are more susceptible to salt attack than the darker, more well-fired ones.

Rising damp is caused by capillary suction of the fine pores or voids that occur in all masonry materials. The capillaries draw water from the soils beneath a building against the force of gravity, leading to damp zones at the base of walls. Many traditional buildings were constructed on footings of dense stone which helped reduce the upward passage of water (Figure 1). In modern construction rising damp is prevented by the insertion of a damp-proof course (DPC) which is generally a 0.5 mm thick sheet of polyethylene (plastic). Because many nineteenth century buildings were constructed without DPCs and because some DPCs have failed, been bridged, or damaged, there are now common problems of dampness at the base of walls. In most cases that dampness will have salt associated with it.

Salt attack is the decay of masonry materials such as stone, brick and mortar by soluble salts forming crystals within the pores of the masonry. As the salt crystals grow the masonry is disrupted and decays by fretting and loss of surface skins. The salt commonly comes from the soils beneath and is carried up into walls by rising damp. When the dampness evaporates from the walls the salts are left behind, slowly accumulating to the point where there are sufficient to cause damage. Repeated wetting and drying with seasonal changes leads to the cyclic precipitation of salts and the progressive decay of the masonry.

One of the difficulties for the casual observer is that salts are not always apparent, and so their role is often not appreciated (Figure 2).

As well as the quality of building materials, and of construction and subsequent maintenance, climate and soil conditions are strong determinants of the severity of salt damp problems. Across Australia the wide range of climate and soil types leads to a great diversity in the degree and extent of salt damp. Adelaide is well known for its bad salt damp; this is because it has hot drying summers and very salty soils, whereas in Sydney the more humid climate and lower salt levels means the decay rates are slower. Age is another important factor; many buildings that have only a mild damp problem at present may, with time, accumulate sufficient salts to cause major decay.

Once salt concentrations are high enough to cause damage repairs will only be successful if they include treatment of both the damp and the salt.

The next three pages contain important information: some common Questions and Answers, a summary of the Seven Key Steps needed to manage a salt damp problem and some fundamental Dos and Don'ts.

2.1 Question and answers

Q My house has bad damp and there is salt bursting through the interior paintwork. Which of the damp-proofing treatments should I use?

A Wrong question. You first should make sure that the source of dampness is minimised and carry out other basic housekeeping measures. Work through the Seven Keys Steps to deal with the problem. Depending on the circumstances, you may need to use a combination of several methods. Be aware that many damp-proofing contractors specialise in one treatment method only, so seek independent advice.

▶ See the Seven Key Steps on the next page and also Part 2 of this guide.

Q Unlike the first enquiry, my house seems to have dampness in some places but no signs of salt. Does it need a damp-proofing treatment?

A Not necessarily. The problem may be eliminated or minimised to an acceptable degree by basic housekeeping measures, such as attention to plumbing and drainage. Check these first and make any repairs needed before considering damp-proofing.

▶ See Section 12: *Good housekeeping*

Q There is mould on the timber inside the built-in cupboard in the corner of the living room. What should I do?

A Mould is due to high humidity, the source of which should first be identified. If it's because of damp walls, the problem may be solved simply by ensuring that the existing underfloor ventilation is working properly. Clean out vent grilles and monitor air flow. More vents may be needed if changes to the house have blocked previous air passages.

▶ See Section 12.3: *Underfloor ventilation.*

Q Our school chapel has damp patches in the wood blocks of the parquet floor. Years ago there was some damp treatment to the walls at one end. Could they be related?

A Yes. When we inspected the outside we found that the ground had been built up over the damp-proof course, which was the reason for the previous (unnecessary) treatment. It is very likely that the underfloor spaces are too damp because of moisture penetrating through the walls from the built-up ground. Lower ground levels to expose the DPC, check underfloor ventilation and make sure all gutters, downpipes and drains work properly. Monitor for a year before making further changes.

▶ See Sections 11: *Diagnosis* and 12: *Good housekeeping*

Q I'm having split-system air conditioning installed in my old stone house and the contractor wants to put the external fan unit against the side wall. Could that be a problem?

A Yes, it could. As well as detracting from the aesthetic qualities of your house, the fan blowing warm air against the wall will encourage evaporation and focus salt damage on the area behind the unit. Site the fan unit, and the condensate drain, well away from valuable old walls.

▶ See Section 6: *Salt attack.*

Q We had our historic presbytery treated for damp with chemicals, yet the mortar is still eroding from between the bricks. Have the chemicals failed and should we have it done again?

A Not necessarily — the water-repellent zone formed by the chemicals may be working OK as a damp-proof course. The problem may be salts remaining in the walls above. Remove the salts and monitor before considering any further damp-proofing treatment.

▶ See Sections 6, 13, 14 and 16.3 and also Figure 43.

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2.2 Seven Key Steps to dealing with salt damp

This is a summary of the Seven Key Steps to successfully dealing with salt damp. These steps are explained in detail in Part 2 of this guide beginning with Section 10: *Approach*.

1. Accurate diagnosis of the cause

- is it rising damp? or is it falling damp? or a combination? or
- is the damp penetrating sideways from a localised source, or
- is it condensation on internal surfaces?
- is there an existing DPC that is buried or otherwise bridged?
- how bad is the problem — does it really need major works?
- is there a lot of salt? what is its source?

2. Good housekeeping is fundamental

- ensure gutters and downpipes are working
- ensure rainwater is carried well away from base of walls
- ensure site is well drained — no ponding against walls
- minimise splash from hard pavements into walls
- maintain about 200 mm between DPCs and ground level
- check for and fix any plumbing leaks, including sewers
- check for fungal rot, borers and termites in damp floor timbers
- ensure adequate (but not too much) underfloor ventilation
- monitor changes, for these may be sufficient.

3. Treat mild damp sacrificially

- use weak mortars in eroding joints, or
- weak plasters and renders to control damage
- monitor changes before considering further treatment
- ongoing sacrificial treatments may be sufficient.

4. Remove excessive salts

- remove surface salt deposits by dry vacuuming, then
- use captive-head washing for near-surface salts
- use poultices of absorbent clay and/or paper pulp
- use sacrificial plasters, renders and mortars.
- monitor effectiveness — re-treat if necessary
- periodic maintenance treatments as required.

5. Review results before proceeding

- allow at least one year of monitoring
- account for unusual events — storms, floods, drought, etc
- routine maintenance activities may be sufficient.

6. Inserting damp-proof courses

- undersetting with mechanical DPC, and/or
- slot sawing with mechanical DPC, and/or
- impregnation of chemical DPC, and/or
- active electro-osmotic damp-proofing.
- install DPCs at a level that will also protect floor timbers
- monitor for 'leaks'.

7. Desalinating walls

- when salts abound, do not just insert DPC
- also remove excessive salts from above DPC
- use poulticing, captive-head washing and sacrificial treatments
- monitor annually for further salt attack
- re-treat if necessary until salts are reduced to a less harmful level.

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2.3 The Dos & Don'ts of damp

Dos:

Do go out in the rain (the heavier the better) and check gutters and downpipes for blockages, leaks and overflows. Also check around the base of the building for water lying against walls. Fix leaks and make any improvements needed to site drainage.

Do check for the presence of a DPC — and ensure that it is continuous, and not 'bridged' by built up paving and garden beds.

Do remember that damp walls increase the risks of fungal rot and termite attack to floor timbers — always check beneath timber floors.

Do consider the possibility that your old building may have had previous treatments for rising damp, and that these may be obscuring the extent of the problem. Thorough investigation before commissioning works will be important to defining the nature, scope and likely costs of any repairs.

Do clean out existing air vents regularly — and monitor results before deciding to add new ones.

Do consider the possibility of salt attack decay into wall cavities — always inspect cavities for accumulation of debris (and corrosion of ties).

Do consider the implications of drying out the soils beneath your building. If it is founded on reactive (expansive) clay soils excessive drying could lead to structural cracking as a result of differential settlement. On reactive soils the challenge is to strike a balance between limiting cracking and minimising rising damp. The unhappy medium might be a bit of each.

Do get independent advice — that way there should be no pressure to use a particular product or system. Check your adviser's credentials.

Don'ts:

Don't use hard cement mortar to repoint failed lime mortar joints — that will just drive the damp further up the wall and may also damage the bricks.

Don't even think about sealing walls with water-repellent coatings.

Don't mulch your walls. Move garden beds away from the base of walls and remove irrigation to prevent spray and ponding against walls.

Don't dismiss the old tar and sand DPC — reduce the damp 'stress' on the walls, repair the DPC, use sacrificial mortars in the joints if necessary, and monitor results before considering an expensive new DPC.

Don't undertake insertion of any form of DPC until all the basic housekeeping measures have been completed and their effectiveness assessed over a period of time (at least a year).

Don't accept the cheapest quote for chemical dampcoursing without checking the contractor's references and the details of the proposed works such as drill hole spacing and depth, and how the contractor will determine when sufficient fluid has been impregnated.

Don't try to get away with using less chemicals and then locking in the inevitable damp with waterproof plasters — your client has read this too!

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3 Previous investigations

▶ The first edition of this guide was jointly published in South Australia in 1995 by the Heritage Branch, Department of Environment and Natural Resources and the City of Adelaide under the title *Rising Damp and Salt Attack*.
See *Further Reading* for details of the publications mentioned in this section.

In South Australia in the 1960s and 1970s there were many cases of failed damp treatments as the salt damp problem was poorly understood. So many complaints were made to consumer affairs that the State government established a Salt Damp Research Committee which operated in the period 1974 to 1982. The committee produced several reports and guides, held a national conference in 1978 and commissioned scientific research.

More recently, the developing problem of soil salinity across large parts of Australia has resulted in previously sound buildings succumbing to salt damage as rising water tables bring salts closer to the land surface. Increasing soil salinity is not only an issue for the major dryland and irrigated areas such as the Murray Darling Basin. It is also a problem in coastal areas, where expanding cities and towns are exposing and building on soils containing salts, including the problematic acid-sulphate soils.

The NSW Salinity Strategy was launched in 2000 and a component, the Local Government Salinity Initiative, provides training, education and technical support. The Initiative has produced a series of booklets and guides, and has held several conferences on urban salinity. Note that, in respect of damage to buildings, the terms salinity and urban salinity are synonymous with salt damp.

Responding to increasing salinity problems, some local councils are requiring higher standards of construction of modern buildings, particularly in regard to concrete slabs and footings for housing. This guide is about existing buildings and is focused on those that have deficient, absent or bridged damp-proof courses. Even buildings with good damp-proofing are not immune to salt damage and many will require ongoing maintenance to control the problem (Figure 34).

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4 Porosity and permeability

All masonry materials, whether stone, brick, mortar, earth or concrete block, are to some degree porous: that is, they contain voids or pores. Porosity is measured as a percentage of the volume of the material and ranges from 0.1% for fresh marbles to an extreme 50% for some limestones. Common porosities of sandstones, limestones, bricks and mortar used in traditional construction are in the range 10–30%. Denser materials such as granites, bluestone and slate have porosities around 1-5%. Porosity is a rough guide to durability: the higher the porosity, the less durable will be the material. Pore size is an important factor: materials with a lot of very small pores are generally less durable than materials with fewer but larger pores.

The degree to which the pores in a material are connected is known as permeability. Closed cell foam has lots of pores but little permeability, whereas a kitchen sponge depends on both porosity and permeability for its capacity to absorb water and release it again when squeezed out. Most masonry materials have some permeability: water and air can move through them to varying degrees. Some materials are relatively impermeable and these include granite, marble, slate and dense concrete. Totally impermeable materials such as plastic DPCs are often described as impervious.

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5 Walls breathe

When a wall warms up after a cool night, the air contained within its pores expands as it warms and a small proportion moves out of the wall via the connected pores. As the wall cools down again the air within contracts and air moves back into the wall from the atmosphere. And so masonry walls 'breathe' – out as they warm and in as they cool. Breathing occurs on a daily basis, or more frequently in periods of variable weather; breathing is shallow when there is little temperature variation and deepest when the daily range is greatest. Of course, walls don't actually breathe in the human sense: they just sit there while changes in temperature (and air pressure) do the work, but the 'breathing' analogy is a convenient way of understanding frequent exchanges of air from masonry to atmosphere and back again.

If the air drawn into a wall is humid and if the wall material cools below the dew point then some of the water vapour in the humid air will condense as water droplets within the pores of the masonry, though the wall will still be 'dry'. During warmer and drier times some of this water will evaporate and leave the wall as it breathes out. And so apparently dry walls commonly contain water, the amount varying with changes in the season and climate. If there are salts or other hygroscopic (moisture-attracting) materials in the masonry then the amount of water drawn into (and retained in) the wall can be sufficient to make the wall visibly damp, even in dry weather.

Anything that prevents a masonry wall breathing will reduce its life expectancy. Coatings that are designed to seal the surface of masonry walls (and so 'protect' them) risk trapping moisture behind the coating and causing a damp problem elsewhere, such as on the other side of the wall. If there are appreciable salts in the wall, the damage caused by the inappropriate use of coatings can be dramatic (Figure 3).

Figure 3 Inappropriate use of water repellent coating, trapping moisture and salts and causing loss of the sandstone's natural case-hardened surface. Beneath this 'skin' the stone can be quite weak.

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6 Salt attack

Figure 4 Thin needles of salt extruding from the top of a window arch. A slipped roofing slate punctured the copper roof gutter, allowing rainwater to wash salts into the stonework.

Figure 5 Salt attack in bricks causing disruption and loss of the fireskin, the harder outer surface that develops during firing in the brick kiln.

Salt attack (or salt weathering) is the term used to describe the damage caused by soluble salts crystallising within the pores of masonry materials. Salts are brought into the porous masonry in solution in water by a variety of means described later under Rising, Falling and Penetrating Damp (Sections 7 & 8). During a dry period, when the water evaporates from the wall, the salt will be left behind (as salts can't evaporate) and the salt solution in the wall will become more concentrated. As more salts are brought into the wall the salt solutions are further concentrated as the moisture evaporates. When the solution reaches a condition known as saturation, or supersaturation (depending on the type of salt), crystals will begin to form.

When the rate of evaporation from the wall surface is low (such as in humid climates, or in cellars and basements with little air movement) the evaporative front may be at or very near the surface, in which case salt crystals will grow as long thin needles, extruding from the wall face (Figure 4). This is known as efflorescence and is commonly seen as a relatively harmless white powder on the surface of new brickwork.

However, when the rate of evaporation is much greater, the evaporative front will be inside the wall and salts will crystallise within the pores of the masonry (subflorescence). The force exerted by rapidly crystallising salts is very high and sufficient to disrupt even the strongest masonry material. Crystal growth leads to either grain-by-grain loosening, which produces fretting and crumbling of the surface (particularly to soft mortars) or to delamination of a complete skin, such as the case hardening found on many sandstones (Figure 3) or the fireskin on bricks (Figure 5).

Cyclic wetting and drying is an important driver of salt attack decay. When salts first disrupt masonry they enlarge the pores slightly. After a cycle of wetting and drying, salts fill the enlarged pores and the new crystal growth further disrupts the masonry and enlarges the pores some more. Each cycle may produce only tiny changes, but cumulatively they result in the progressive decay of the masonry material.

6.1 Which salts?

Salts consist of a combination of positively and negatively charged ions known as cations and anions. The table below shows those that make up the salts commonly encountered in walls.

Cations (+ve)	**Anions (–ve)**
Sodium (Na^+)	Chloride (Cl^-)
Potassium (K^+)	Sulphate (SO_4^{2-})
Magnesium (Mg^{2+})	Nitrate (NO_3^{2-})
Calcium (Ca^{2+})	Carbonate (CO_3^{2-})

Salts may consist of a combination of any cation with any anion, provided there is a balance of positive and negative charges. Thus sodium chloride (table salt) is written NaCl, while sodium sulphate is Na_2SO_4 and calcium chloride is $CaCl_2$. Sodium chloride, sodium sulphate and calcium sulphate gypsum are commonly found causing salt attack problems in walls.

Salt attack can occur simply through changes in humidity. Some salts have water (H_2O) combined in the crystal structure and may exist in several different hydration states. These include sodium sulphate, which can exist as Na_2SO_4 or as $Na_2SO_4{\cdot}10H_2O$, and is a particularly damaging salt. Salts that are deliquescent at normal humidities, such as magnesium chloride ($MgCl_2{\cdot}6H_2O$) are also problematic; they attract water from moist atmospheres, dissolve, and then crystallise again when the humidity drops, or on rapid cooling.

Not all the possible combinations of cations and anions shown in the table are very soluble and hence damaging. Calcium carbonate ($CaCO_3$) is relatively insoluble, which is fortunate as it is the principal component of limestone, marble and the cured lime in mortars.

▶ For information about testing for salts go to Section 11.3 *Chemical analyses for salts*. Do-it-yourself salt testing is explained in Box 4.

The amount of salt required to cause damage will vary and will depend on the type of salt(s), the nature and condition of the masonry, including its pore structure (pore size and distribution) and the cohesive strength of the material. A general rule of thumb is that more than about 0.5% by weight of salt is considered cause for concern and reason for considering salt removal (desalination).

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Sources of salts in walls may be one or more of the following:

- saline soils and groundwater
- sea-spray for coastal sites
- air-borne (meteoric) salts — even in inland locations
- air pollutants
- inorganic garden fertilisers
- biological sources — pigeon droppings, micro-organisms, leaking sewers
- salt naturally occurring in the stone, brick clay, or mortar sand
- salty water used for puddling brick clay or mixing mortar
- salts used for de-icing roads in cold climates
- cleaning compounds that contain (or react to produce) salts in walls.

The type of salt may be a guide to its source; e.g. high levels of nitrate salts may indicate leaking sewers or confirm that a building was once a stable.

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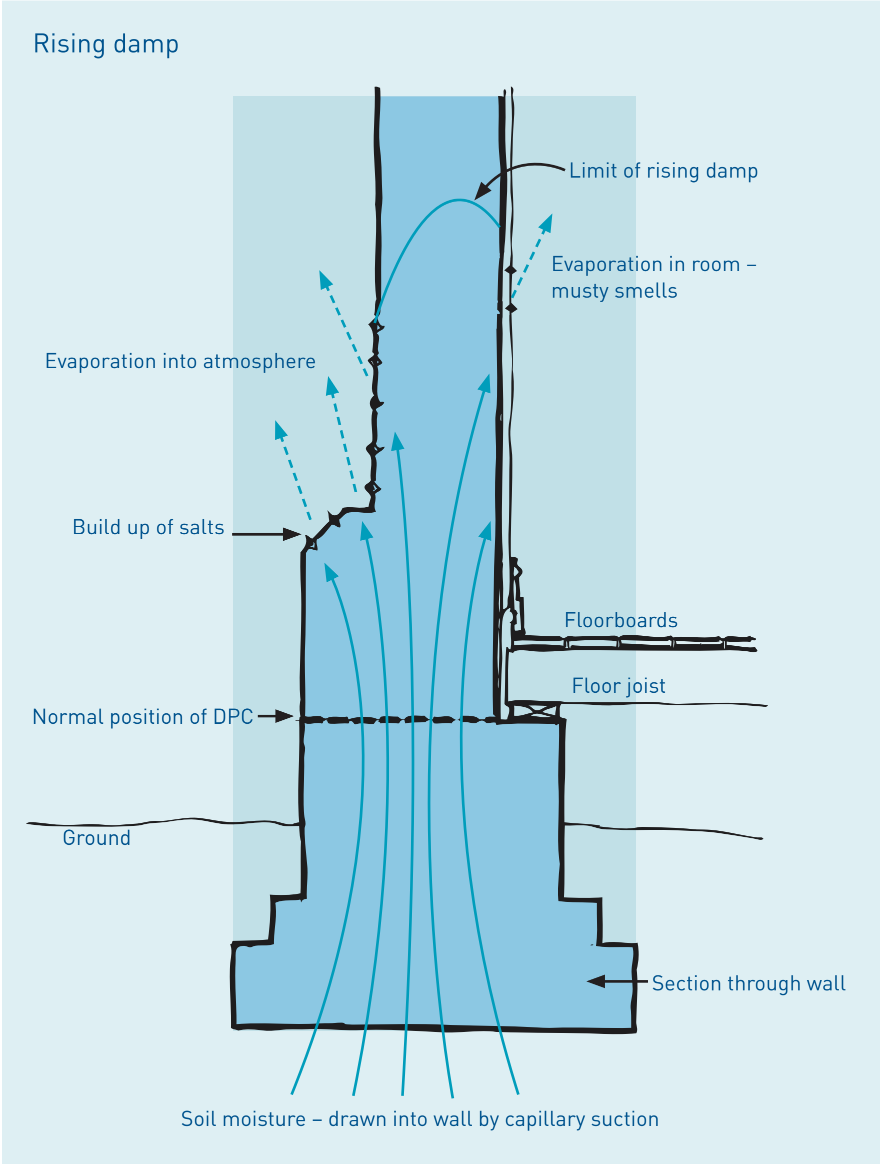
Rising damp

Figure 6 Section through a solid wall showing the path of rising damp which is caused by the suction of porous masonry. The pores effectively form a network of capillaries which draw soil moisture against gravity. Damp rises in the wall and eventually evaporates from the wall surfaces. As well as damaging masonry materials, the dampness may lead to fungal rot and insects (borers and termites) in the floor timbers. Today it is normal building practice to include a moisture barrier known as a damp-proof course (DPC) across the base of the wall below all floor timbers and at least 150 mm above ground level



Rising damp is caused by capillary action (or suction) drawing water from the ground through the network of pores in a permeable masonry material. Capillary suction becomes stronger as the pore size gets smaller; if the pore size is fine enough damp may rise many metres in a wall, until the upward suction is balanced by the downward pull of gravity (Figure 6).

In practice, the height to which water will rise in a wall is limited by the rate of evaporation of water from the wall surfaces. The evaporation rate for external surfaces is related to the nature of the masonry materials, surface coatings, climate, season and siting. In Australia the normal exterior height limit for rising damp ranges from 1.0 to 1.5 metres above ground level, whereas in cooler, more humid climates damp may rise several metres before evaporating. The evaporative zone is commonly from 0.5 to 1.2 metres above ground level. There is often little evaporation up to 0.3 metre

Figure 7 Typical blistering of paintwork and damage to internal plaster due to the combined effects of rising damp and salt attack. The skirting is a cement moulding and also shows salt damage.

above ground because the air near the ground is more humid and is more slowly moving. Trees, gardens, fences and nearby buildings will influence the particular circumstances.

Heating, ventilation and air-conditioning play a critical role in determining the height to which damp will rise on internal walls: the more ventilation the lower will be the damp zone. Air-conditioners generally dehumidify the air in a room and increase ventilation rates. The addition of heating or air-conditioning will increase the rate of drying and so increase the associated decay. Air-conditioning systems can draw moisture through solid masonry walls and their introduction into older buildings can be problematic.

As moisture evaporates from either face of a wall, more moisture is drawn from below. The process is dynamic: there is often a continuous upward flow of moisture, slowing or stopping only in dry weather and particularly during droughts. The rate of flow depends on the supply of water, evaporation as described, and the permeability of the masonry.

Rising damp may show as a high-tide like stain on wallpaper and other interior finishes, and when more severe, as blistering of paint and loss of plaster (Figure 7, and also Figure 15). Musty smells are common in poorly ventilated rooms and particularly in cellars and basements (see Box 1: *Damp rooms may be unhealthy*). Externally, a damp zone may be evident at the base of walls with associated fretting and crumbling of the masonry (Front cover & Figure 2).

Damp rooms may be unhealthy

Damp conditions promote the growth of moulds, tiny members of the fungal kingdom that include rots and mushrooms. Moulds have the potential to cause health problems. Inhaling or touching mould or mould spores may cause allergic reactions in sensitive individuals. Moulds can also cause asthma attacks in people with asthma who are allergic to mould. Research on mould and health effects is ongoing. Indoor mould growth can and should be controlled by controlling moisture levels. Keeping walls relatively dry is a sensible precaution. In building science terms, surface relative humidities (the relative humidity of surfaces such as walls) should be kept below 80% for periods of a month at a time. This is readily achieved in well-ventilated housing in warmer parts of Australia.

Box 1

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7.1 The damp-proof course (DPC)

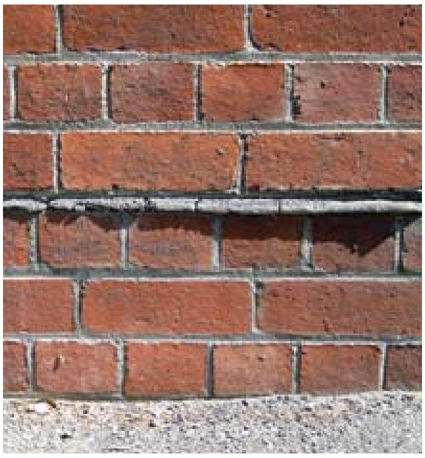

Figure 8 Many late nineteenth and early twentieth century DPCs were a mix of tar and sand that was laid hot. Being viscous, some have harmlessly extruded a little under the weight of the overlying masonry.

To prevent rising damp it is now normal practice to build in an impervious barrier at the base of the wall just above ground level and below any floor timbers. This is known as the damp-proof course (DPC) or sometimes just as the dampcourse. Modern DPCs include the common embossed black polyethylene sheeting. The standard thickness is 0.5 mm and there is a heavy duty grade, which is 0.75 mm thick and has a higher impact resistance, providing improved resistance to damage during laying. Careful building practice is necessary to ensure that the DPC is not punctured or otherwise damaged during construction, and that it forms a barrier across the full thickness of the wall.

Many nineteenth century buildings in Australia were built without DPCs. By the third quarter of the nineteenth century the need for damp-courses seems to have been recognised, though not always practised. Early DPCs included roofing slates laid in mortar with an overlapping second layer, sheets of glass, lead, hardwoods, bitumen-impregnated fibre, felt or paper, and various asphalt and tar-based compositions, including a widely used tar and sand mix which was laid hot (Front cover & Figure 8).

Some of the most effective DPCs used were glazed hard-burnt ceramic tiles or bricks, often with perforations allowing ventilation (Figures 9 & 10). These DPCs were laid without mortar in the perpendicular joints to prevent moisture passage through permeable mortar. The open joints also allowed through-wall ventilation. It is a great pity that glazed brick units suitable for DPCs are not made today as they have many advantages.

Figures 9 and 10 Hard burnt and glazed ventilating ceramic tiles and bricks. Made for the purpose, these are among the best dampcourses ever used, particularly the example at left from 1879. At right is a 1930s example which (together with its adjacent brickwork) is a remedial undersetting of an 1840s church of rubble limestone. Both examples were laid with open perpendicular joints to prevent damp travelling through the permeable mortar. In both cases salt attack is damaging the masonry below the DPCs — and each building will need treatments to control the salts (see Sections 13 & 14).

More recent DPCs have included thin copper or aluminium sheets coated with bitumen and then with talc or mica flakes to prevent adhesion when rolled. These have not performed well in corrosive (i.e. salty) environments. There is also a composite DPC which has a metal core coated in bitumen with an external coating of polyethylene. Because the plastic coating is very thin (0.1 mm) it is easily damaged, exposing the metal which is then susceptible to corrosion. Waterproofing additives for mortars have been commonly used, generally in the first three courses of brickwork above the concrete footing. Mortar additives should not be relied on as a sole means of damp-proofing.

Very few DPCs are truly durable and damp-proof; of currently available materials, only polyethylene has proved impermeable and resistant in very corrosive environments. *The Building Code of Australia* (see Box 8) has provisions for acceptable damp-proof course materials.

While most early DPCs would not meet modern standards, many have performed quite well, particularly where the rising damp 'stress' on the wall is relatively low. Existing DPCs, such as those based on asphalt and tar, should not be assumed to be defective simply because they are old. The better ones continue to perform well today.

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7.2 Bridging the DPC

▶ For more advice on the position of DPCs go to Box 2: *Location of damp-proof courses.*

Rising damp is often caused by bridging the damp-proof course: a moisture pathway or bridge that negates the effect of the DPC. Bridges may be caused by rendering or plastering over the DPC. Pointing over the external face of a DPC will also cause a bridge, though it is important to be aware that asphalt or tar-based DPCs were often specified to be pointed over in hard cement, so as to retain the viscous DPC while minimising permeability. Examples where this pointing has failed are common, with the DPC extruding slightly from the joint (Figure 8). Poorly installed DPCs that do not form a barrier across the entire wall thickness will be bridged by mortar in the joints or cavity. Concrete floors or external paths can form a bridge if the concrete, or the fill beneath, abuts the DPC without some form of vertical damp-proofing. Build-up of garden beds and pavements against walls can also bridge the DPC (Figure 11). To be effective a DPC needs to remain about 200 mm above ground or paving level.

Bridging the damp-proof course

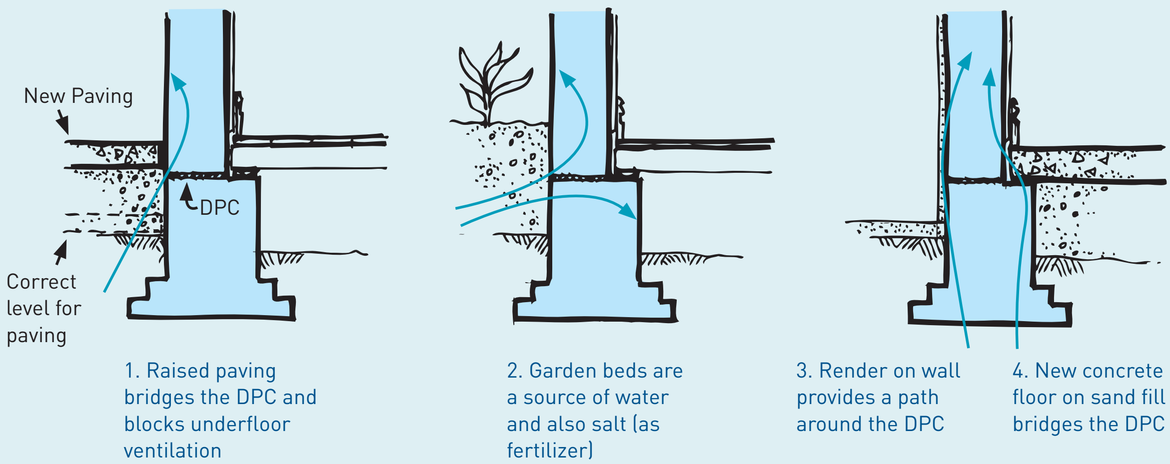


Figure 11 Bridging the damp-proof course. Four examples of how changes to a building can create a path, or bridge, around an existing damp-proof course. Bridging by build-up of paving or garden beds is a common cause of rising damp problems. See also Figures 29 and 49 for further examples of bridging.

7.3 When the damp contains salt

By itself, rising damp causes wet walls and musty smells but limited decay of masonry (except to particularly susceptible materials, such as those containing swelling clays — some earth materials and some clay-rich sandstones and limestones). It is when salt is present in the soil that salt attack combines with rising damp to cause substantial decay. In practice some salt is likely to be associated with most cases of rising damp, particularly in older buildings that have accumulated salts over a long period of time. Thus it may be that an old building with deficient, absent or bridged DPCs is badly damaged, despite relatively low salinity in the soil beneath. The importance of time is considered further in Section 9: *Further factors*.

Once rising damp has drawn enough salt into the wall so that the concentration of salt in the masonry is higher than in the soil below, the very presence of the salts helps to perpetuate the damp, increasing the problem. This is because of the hygroscopic and deliquescent nature of many salts: their tendency to attract water and then dissolve into it (think of the dinner table salt shaker in humid weather). Deliquescence keeps salty walls wet in humid weather and then solute suction (the osmotic pressure of a salt solution) draws more water towards the higher concentration of salts, compounding the capillary suction and adding to the rising damp (Figure 12).

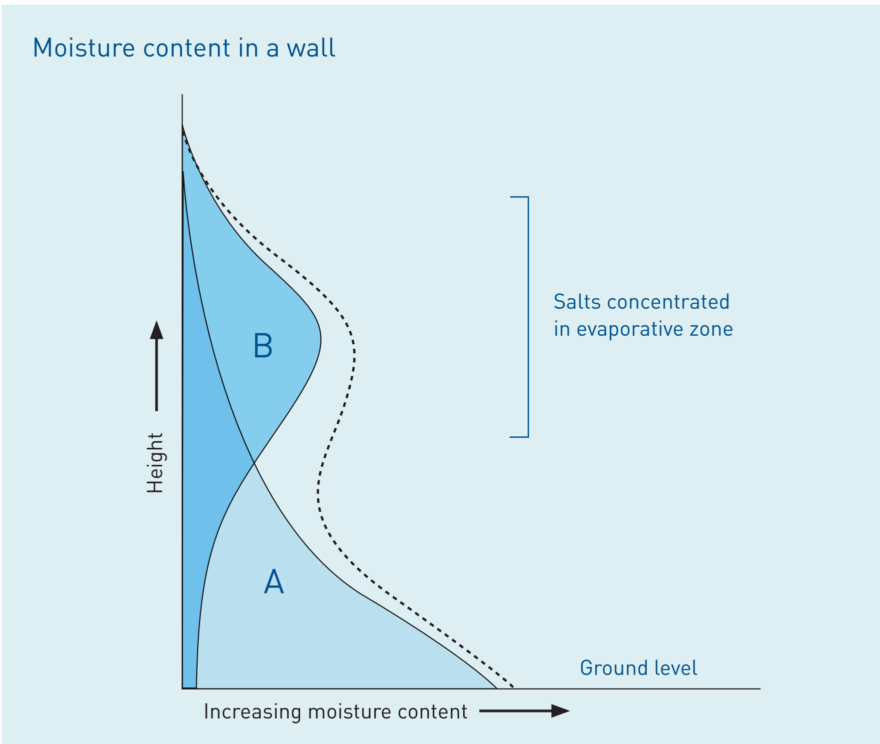


Figure 12 Moisture content in a masonry wall due to A, capillary action (rising damp) and B, hygroscopic salts. The total moisture content is shown by the dashed line and is the sum of A and B. The relative contributions of A and B to the total will depend on the amount and nature of the salts in the soils beneath, on the climate (humidity, temperature and wind speed) and on time (the older the wall the longer it will have had to accumulate salt).

8 Other forms of damp

Most damp-related decay is caused by salt attack in combination with rising damp, but other forms of damp can also cause substantial damage.

8.1 Falling damp

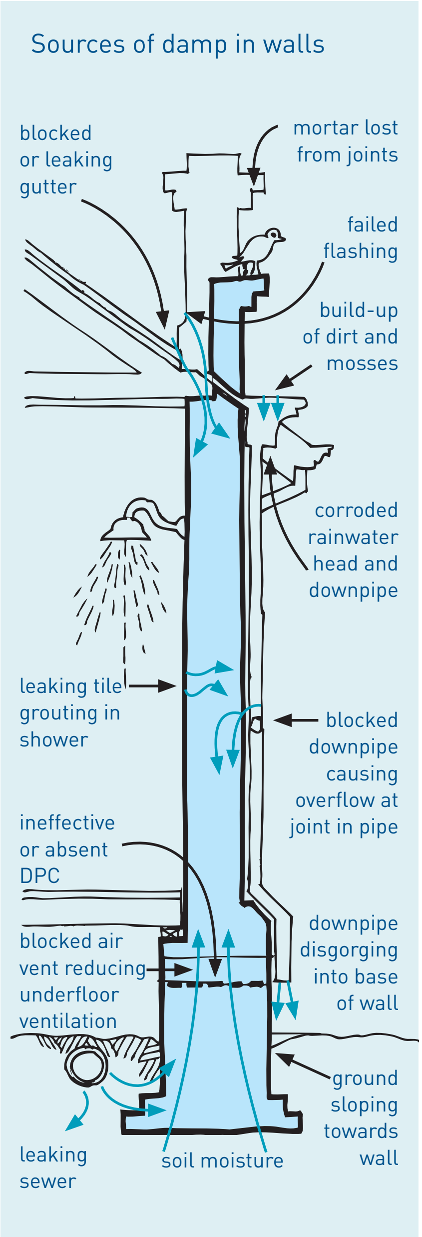


Figure 13 (above) The many sources of damp in walls.
Figure 14 (right) Two examples of falling damp. Overflow from the blocked rainwater head is made apparent by dark green algae. The coping above the rainwater head is allowing water through to the stones below. Salt attack is causing these stones, above and to the left of the rainwater head, to decay.

As the name suggests, falling damp is moisture entering masonry walls from above and percolating downwards through the network of pores that most materials possess. The numerous sources of falling damp (Figure 13) include failed roof coverings, blocked or leaking gutters, failed flashings and joints that have lost their mortar. Build-up of dirt and mosses on upper surfaces of parapets and cornices encourages water retention which in turn promotes downward percolation through the masonry. Most cases of falling damp lead to relatively localised patches of damage.

The typical debris that builds up in roof gutters and on parapets (such as fallen leaves, bird manure, mosses and dirt) contains weak acids which will contribute to masonry decay by slowly dissolving weaker components leading to progressively more porous and permeable materials. Salts also accumulate on the tops of buildings, not only near the coast, where sea spray is a major factor, but even in central Australia, where wind storms whip up salts from the dry salt lakes and where tiny particles of salt rain from the sky. Though the rates of accumulation of air-borne salt are relatively low, with time a building can absorb sufficient salt to cause damage, particularly when it is all concentrated at one point, such as the top of a blocked downpipe or rainwater head. The importance of regular maintenance of gutters and downpipes cannot be over-emphasised (Figure 14).

As with rising damp, the damage caused by falling damp happens not where the moisture enters the masonry, but at the point where it

evaporates from the wall surface and leaves the salts behind (Figures 4 & 14). Tracing damp back to the point of entry can be difficult, particularly when the masonry is rendered and/or painted and the moisture is trapped behind the render or paint coating.

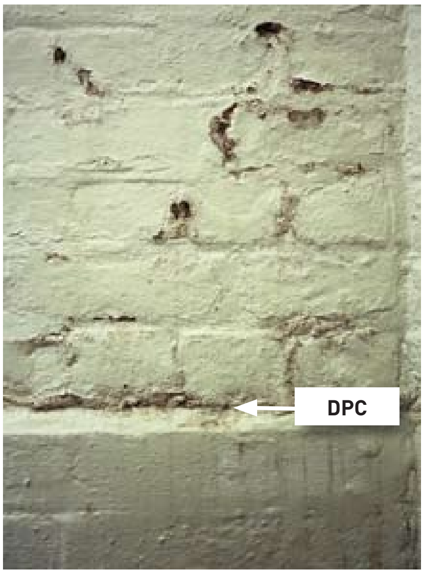
8.2 Penetrating damp

Penetrating damp can be due to leaking water or waste pipes; to failure of tile-grouts in kitchens, bathrooms and laundries; or to defective mortar joints in external walls. Leaking grouting in shower alcoves is particularly common and often shows as damp patches and blistering of paint in the room next to the bathroom. Persistent drips from air-conditioning condensate drains or hot water system overflows can also be a problem. Sources of penetrating dampness such as plumbing leaks can sometimes be difficult to trace and may require a range of sophisticated techniques, including acoustic detection, thermal imaging, moisture meter surveys and the use of tracer gases.

Construction faults may cause penetrating damp. Mortar droppings (snots) caught on ties in wall cavities can provide a pathway for water to travel from outer leaf to inner leaf and so negate the point of having a cavity. Substantial accumulations of snots at the base of the cavity can produce large damp patches on interior surfaces. Prior to the introduction of cavities, all walls were solid and relied on good workmanship and their thickness to limit rain penetration. On the prevailing wind side of a house, 230 mm (nine inch) walls commonly leaked and were often rendered to fill cracks in mortar joints, improve water shedding and reduce water entry. The alternative use of modern paints for this purpose can be problematic, for while limiting water entry, they will also prevent the wall drying rapidly and so may increase, rather than reduce, interior dampness problems.

Like falling damp, penetrating damp generally produces small, localised patches of dampness and decay. Exceptions are cellars and basements, where ground and surface water may penetrate laterally through the walls due to the failure or lack of external damp-proofing or drainage. In these cases damage may be widespread and at first sight may appear to be due to rising damp (Figures 15 & 16). Accurate diagnosis will be critical to successfully managing or remedying such a damp problem.

Figures 15 and 16 In both these examples of penetrating damp the walls are wetter above the DPC than below. At right moisture is penetrating horizontally from a concrete floor, while on the left (in a basement) moisture is coming through the wall from the ground outside. Had the left hand example been an external surface, the paint would have prevented rain from flushing salts out of the wall.



9 Further factors

This section begins with the factors causing salt attack and considers rates of decay in Australia in contrast to those of the United Kingdom. Some important considerations in the management of a salt damp problem are then discussed, providing a theoretical basis for the recommended approach and remedial works of Part Two.

9.1 Factors causing salt attack

For salt attack to occur there must be a combination of the following factors:

- permeable masonry
- available moisture
- available soluble salts
- evaporation

All four factors must be present for decay caused by salt attack to occur. Conversely, decay can be prevented by removing any one factor. While ostensibly an attractive path to preventing salt attack, in reality it is impossible to completely eliminate any one factor.

Permeable masonry. People have sought to make masonry materials impermeable by applying water repellent coatings, which have led to many failures as moisture and salt are trapped behind the coatings (Figure 3).

Available moisture. Preventing moisture entering masonry is one of two factors over which we have some (but not total) control. We can minimise water entry by good design and detailing and by good repair and maintenance practices, but we cannot totally prevent water entry. As noted in Sections 5: *Walls breathe* and 6: *Salt attack*, moisture may enter walls as vapour, and salt attack may be triggered simply through changes in humidity.

Available soluble salts. Salts abound and we cannot change that, but we can reduce the amount of salt in our walls (see Section 14: *Removing excessive salt*), though we will never remove it entirely, nor remove the need for periodic maintenance to control salt attack.

Evaporation. Where there is no evaporation there is no salt attack, the most obvious example being buried masonry such as footings, which if kept wet will not decay. This principle is used in partially uncovered archaeological sites where parts of buildings are displayed through windows into the ground. To prevent salt attack, the masonry in such sites must be kept moist 100% of the time (and there must be no evaporation of that moisture) which means sophisticated temperature and humidity controls. Keeping above ground walls permanently wet in order to prevent evaporation is impractical.

9.2 Rates of decay — comparison with the UK

Our building tradition derives from the United Kingdom where the climate is cooler and wetter than ours and so the rate of transpiration of moisture through walls is lower, though the walls themselves may be wetter. Condensation is a more significant problem, and the misdiagnosis of damp problems as due to rising damp is common. In contrast, the hotter and drier, temperate Australian climate promotes rapid evaporation from wall surfaces and hence greater rates of transpiration of moisture due to rising damp. When coupled with relatively saline soils, the result is much higher rates of decay in this country than in the UK. And so younger Australian buildings can be in worse condition than the much older buildings of northern Europe.

9.3 What to fix — the damp, the salt, or both?

Like our building tradition, our building repair tradition also comes from Europe, and so we have tended to focus on the damp, rather than on the salt. Yet both must be dealt with if our buildings are to be maintained in the long term. Failure to understand this has led to remedial treatments that may have successfully inserted a new damp-proof course but haven't stopped decay, because salts are left in the walls above the new DPC and continue to cycle in and out of solution with changes in humidity. Although the main source of moisture is removed (and the further supply of salt reduced) decay will continue, albeit at a slower rate. **Best practice treatment of salt damp involves removal of salts as well as cutting off or minimising the rising damp.**

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9.4 Managing salt attack with maintenance

Consider the hypothetical (and common) case of a 100 year old house which is well built, with brick walls and lime mortar, and sits up on a well drained block with no ponding of surface water against the walls. Yet the lime mortar of the lower 5–10 courses of brickwork is eroding and in places the loss is up to 50 mm. The bricks are in reasonable condition, showing only the first signs of deterioration. There is no damp-proof course and not a lot of dampness in the walls. On the inside the plasterwork is in good condition with only a few small areas of blistering beneath paint coatings. It is tempting to think that as the house has lasted 100 years, the decay will not be much worse after another 20 or 30 years. Postponing action on this basis would be wrong, as Figure 17 shows. While this graph is notional, it is based on conservation science and an understanding of the rate of decay of materials.

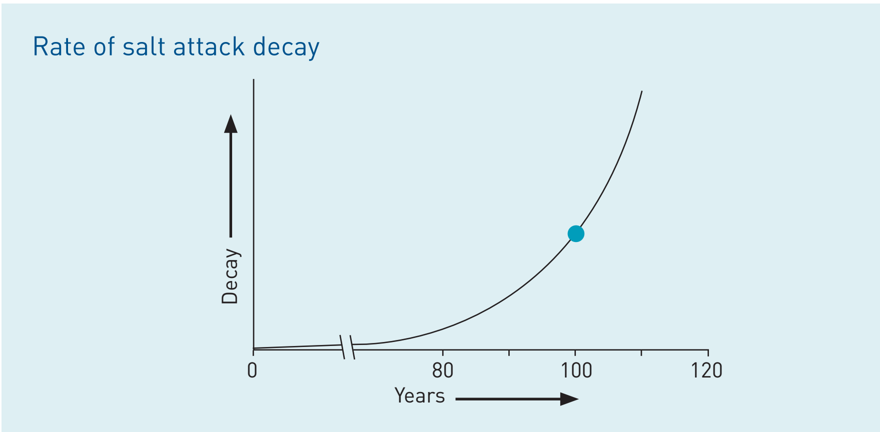

Figure 17 The rate of salt attack decay follows an exponential curve in which there is a long period of little or no decay as salt slowly accumulates in the pores of the masonry. Then when the salt has filled the pores there is a rapid acceleration of decay — the condition of a 100 year old building may be twice as bad after only another 10 years.

There is a long period of almost no decay (in this case about 80 years) during which time salts are slowly accumulating within the masonry. Only then do they fill the pores sufficiently to cause significant salt attack decay. By the time the house turns 100 the decay has accelerated to near its maximum rate (the slope of the line), and in only ten more years the decay will be twice as bad as it is now. There are two important lessons from this. The first is that procrastination is not an option — something must be done, and done soon, or sufficient mortar will be lost to cause partial collapse of the walls (Figure 18).

Figure 18 Extensive loss of lime mortar due to salt attack. The bricks remain sound — protected by the weaker mortar. Any further mortar loss risks local collapse of the brickwork. Successful repair may require dismantling and reconstruction as is done when undersetting (See Section 16.1).

The second is that, by reversing the decay and its cause, it will be possible to effectively reset the position on the graph back to a point where there is little decay. This is shown in Figure 19 which assumes that we have reversed the decay (i.e. put mortar back in the walls) and removed the immediate cause (by taking the salt out) so as to reset the decay clock back twenty years.

▶ For advice on mortar mixes and desalination go to Section 13: *Treating mild damp sacrificially* and Section 14: *Removing excessive salts.*

Repointing, the process of putting mortar back into joints between bricks and stones, is relatively straightforward. Removal of the salts can be achieved partly by raking out the weak mortar containing the salt and partly by desalinating the masonry, though we will never get all of the salt out which is why the vertical line does not go all the way down to the baseline.

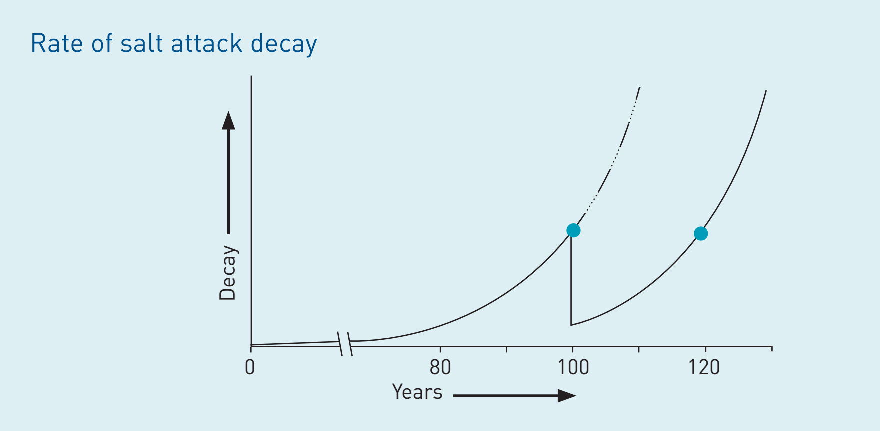

Figure 19 After 100 years decay is reaching its maximum rate and something must be done. By putting mortar back in the walls and by removing the salts we can reset the decay clock back twenty years. The vertical line at 100 years does not go all the way to the baseline because is impractical to remove all the salts. This is an approach which requires ongoing maintenance — every twenty years in this hypothetical case.

Clearly, this treatment does not cure the salt damp — instead it is a maintenance approach of managing the problem and preventing it from getting worse. Like any maintenance it will require periodic renewal — in this hypothetical case, every twenty years.

Importantly, this approach buys time. By reducing salt concentrations so that decay is minimised, the owners and managers of a building have time to review its moisture regime and to determine an appropriate course of action, which may or may not include insertion of a damp-proof course. This is particularly important where the masonry is of heritage value and an objective is maximising retention of historic material.

The foregoing is not an argument for never inserting a DPC. There are many situations — masonry materials with high suction and moderate to high permeability, buildings on low-lying or otherwise poorly drained sites, and sites with heavy clay soils that produce temporary high water tables during rain periods — where a DPC will be an essential part of dealing with a salt damp problem. But for those on well-drained sites and with only mild decay (perhaps because of a partially effective DPC, or low permeability materials), managing the decay by minimising the salts and the moisture 'stress' on walls will at least buy time for consideration of further options. As well as reducing intervention in masonry of heritage value, it may prove to be a cost-effective approach in the long term.

Location of damp-proof courses

The *Building Code of Australia* (see Box 8) Deemed-to-Satisfy Provisions generally require a damp-proof course to be installed in new buildings a minimum of 150 mm above ground level. This is to allow for some subsequent build up of ground level without risking bridging of the DPC. The BCA clearance above ground varies for different circumstances and may be reduced to as low as 50mm in areas protected from the weather by carports, verandas and the like. These provisions have been developed for modern construction practices and are not necessarily the most effective for traditional building forms. There is no upper limit for a DPC and this means that they can be, and often are, more than a metre above ground level, particularly on sloping sites. This negates part of the point of having a DPC as most evaporation from Australian walls takes place in a zone from 300 to 1200 mm above ground level.

This guide recommends that remedial DPCs be installed between 150 and 250 mm (two to three courses of standard brickwork) above finished ground level, with an ideal of 200 mm. Good maintenance practices should be used to ensure that ground levels do not build up and that the 200 mm clearance is maintained. Where the ground slopes, the DPC should be stepped to follow the slope, and so the maximum height may need to locally exceed 250 mm. The minimum height of 150 mm is important to counter the effects of splash from rain strike on adjacent pavements (see Section 12.2: *Site drainage*). Consider installing the DPC at a higher level (250+ mm) in situations where rain splash from hard pavements cannot be avoided. DPCs should always be installed below all floor timbers. Where the floor is below ground level, some form of vertical DPC may be required to prevent moisture penetrating sideways to the timbers. An air drain (Box 5) may be appropriate.

The point of these recommendations is to keep the size of the potential evaporative zone below a DPC to a minimum in order to limit decay due to salt attack (Figures 10 & 34). Decay below a DPC will require ongoing maintenance. See Box 7: *Potential negative impacts of DPC installation* for an additional perspective.

Box 2

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Part 2
Diagnosis, maintenance and repair

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10 Approach

This part of the guide begins with a series of Seven Key Steps which should be followed when dealing with a salt damp problem. These are the steps already outlined in Section 2: *The Basics*. The steps and their section numbers are:

11	Key Step 1	Diagnosing the cause — and the importance of getting it right
12	Key Step 2	Good housekeeping — to minimise the damp 'stress' on walls
13	Key Step 3	Treating mild damp sacrificially — to control salt attack
14	Key Step 4	Removing excessive salts — when normal methods are not enough
15	Key Step 5	Reviewing results before proceeding — important
16	Key Step 6	Inserting DPCs — and the different types available
17	Key Step 7	Desalinating walls — as DPC insertion alone is not enough

Not all steps will be necessary in every case: indeed after diagnosing that the problem is actually a broken downpipe in Step 1 and then repairing it in Step 2, there may be nothing more to do. At the opposite extreme there will be buildings where the extent of damage and the rate of decay are so great that Steps 3, 4 and 5 might be omitted. Different parts of a building may need different treatments — sacrificial treatments may be sufficient for some parts, while other parts may require one or more types of DPC together with desalination. Taking the process step by step is recommended for most circumstances as it ensures that unnecessary work is not done and that more expensive works can be anticipated and planned for over a period of time. Consideration of treatments and options should happen at each stage.

Importantly, it will be apparent from these steps that the decision about inserting a damp-proof course, and what form(s) that should take, are decisions for later in the process.

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Following the Seven Key Steps are sections dealing with particular aspects of treating salt attack and rising damp:

18 Cavity walls
19 Inserting chemical DPCs in internal walls
20 Out of sight, out of mind: the need for improvements to practice
21 Repairs to interior plasterwork
22 Repainting — and allowing walls to breathe
23 Cellars and basements — their particular circumstances
24 Old treatments that should no longer be considered.

The dos and don'ts of damp, a series of points and reminders about good and bad practice when dealing with salt attack and rising damp, is included in Section 2: *The basics.* A glossary of technical terms and a bibliography of further reading are incorporated at the end of the guide.

When dealing with listed heritage buildings always check for any planning or heritage approvals that may be required before undertaking any works.

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11 Diagnosis

Figure 20 Evidence of previous treatment with hard impermeable plaster. Damp is evaporating from above and below the impermeable zone.

Accurate diagnosis of the cause and extent of a damp problem is important. Failure to correctly identify the source of moisture can lead to wasteful and unnecessary repairs which do not solve the problem. Among the questions that should be asked of each case are:

- is it rising, falling or penetrating damp, or a combination of two or more?
- is the problem none of these but just condensation on internal surfaces?
- is there a damp-proof course?
- is the damp problem reasonably uniform around the building, which may suggest failure of the DPC? or
- is it just in one part, suggesting bridging, or a localised source such as a leaking pipe, or failed gutters and downpipes?
- is there a localised source of salt, such as an old brine tank, or fertiliser stockpile?
- where do the hot water system overflow and air-conditioning condensate drains run?
- are there signs of a previous treatment (Figure 20) and what is its nature?
- what is the condition of underfloor spaces, including dwarf walls and floor timbers?
- what is the condition inside the wall cavities?

Because there may be more than one cause of a dampness problem it is wise to complete a thorough investigation, even though a likely cause has already been identified. Ideally, inspections should be undertaken before and after a dry spell to avoid the possibility that rain may have washed salts back into the walls, making their presence less obvious. Follow-up inspections allow monitoring of changes and are highly recommended.

11.1 Independent advice

Advice should be sought from an independent specialist, so avoiding bias towards any particular commercial treatment. Such advice might be provided by consultants specialising in the field and by architects, engineers, licensed builders or building consultants. When seeking suitable consultants always ask for references and evidence of their experience in this type of work. It may be appropriate that their investigation be undertaken according to Australian Standard AS4349.0—2007, which provides for inspection of "particular technical aspects". Such an inspection should include a thorough investigation of all walls (inside and out), stormwater drainage and external site conditions such as paving against walls. The condition of the masonry walls should be described, as should the nature, condition and location of damp-proof courses. Wall cavities and spaces beneath timber floors must be inspected and an assessment made of the existing underfloor ventilation. Be aware that soil in underfloor spaces may have been treated with organochlorine termiticides — always take appropriate safety precautions.

▶ Ask your State heritage agency to identify possible advisers.

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11.2 Moisture meters

Moisture content of wood and masonry materials can be conveniently measured with hand-held meters. These are of several types, measuring one or more of several related electrical properties, including the conductivity (or conversely, the electrical resistance), the impedance, or the fringe capacitance of a material. The presence of water can significantly alter these properties.

Some meters have two sharp probes which are pressed against, or pushed into, the material, some have smooth sensor pads and some have both. Using meters equipped with sensor pads rather than sharp probes avoids damage to finishes such as paint and wallpapers, which is important for buildings of heritage value, but there is a place for both types in surveying walls.

Because the presence of salts also has a considerable effect on the electrical properties (e.g. increasing conductivity) meters cannot distinguish between relatively dry but salty walls, and those that are wet but free of salt. Great care is needed in interpreting their results. It is common in salty walls to get a reading of greater than 100% moisture content, an unreal figure, leaving no room for the masonry itself! The only valid result is a zero figure indicating no moisture and no salt, though as different materials have different electrical properties, figures above zero may not necessarily indicate the presence of any moisture or salt. Further, a moisture meter survey may find high 'spots' which are actually due to buried cabling, pipes, or other metal objects.

Caution: Moisture meters should never be used as the sole basis for diagnosing a damp problem. Because soluble salts considerably change the electrical properties of masonry, moisture meters should never be used on their own to prove that a wall is unacceptably damp.

Although moisture meters should be used with caution, they can be very useful aids for quickly mapping the extent of damp patches in walls. Always check high on a wall (well above the rising damp zone) for any moisture that may indicate another source of damp. Meters are also useful for monitoring changes over time — use the same meter to ensure reliable comparisons.

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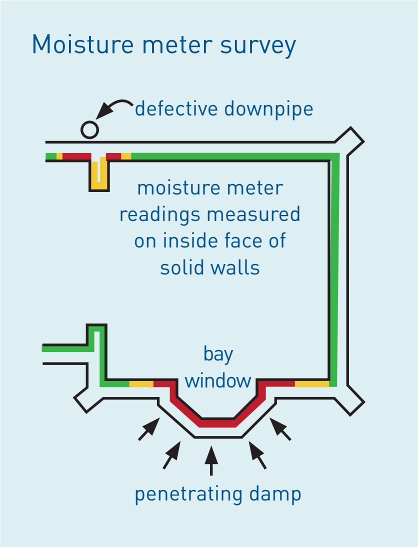

Figure 21 Moisture meter survey with results shown colour coded as on meter; red = high, yellow = moderate, and green = low.

In addition to a numerical readout, some meters show their results on a colour coded scale of red, yellow and green (high, moderate and low). Using this simple scale is often the best way to survey a building as it gives a quick guide that is easily read and understood. Figure 21 shows the results of such a survey measured on internal surfaces of solid walls. Most of the dampness is around the bay window but there is a patch on the opposite wall that is due to a failed downpipe allowing water to run down the outside of the building. The water percolates through the solid wall to produce the narrow red zone measured on the inside. This zone can be traced well up the wall proving that the source is not rising, but falling damp.

More accurate on-site measurements of moisture content can be obtained using carbide meters. They require samples collected from the wall using an electric drill. For greater accuracy still, samples taken from the wall are kept in sealed containers until tested in a laboratory for the weight loss of oven-dried material. An assessment of the moisture that is due to the presence of hygroscopic salts can then be obtained by allowing the dried samples to reach equilibrium in a controlled atmosphere of 75% relative humidity and reweighing. This is the only method that will distinguish between moisture due to rising damp and that due to hygroscopic salts (see Figure 12).

11.3 Chemical analyses for salts

Depending on the nature and scale of the project there may be value in understanding the type and quantity of salts present. Understanding how much salt is in a wall may be important in deciding on the extent of remedial works and, later, to determining the success of desalination treatments. As noted in Section 6.1, a general rule of thumb is that more than about 0.5% by weight of salt is cause for concern. A knowledge of the type of salts will help understand their source and may point to a particular problem (see Box 3).

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Contaminated materials

Beware of contaminated materials such as sands and other aggregates. Chemical analysis of the strong efflorescence in the photograph shows it to be predominantly magnesium sulphate (epsomite), a very soluble salt. Its origin is almost certainly from contaminated dolomite quarry sand used as a bed for the concrete paving in the foreground. A former quarry produced a dolomite aggregate for concrete and roadmaking and the crusher fines (quarry sand) were widely used as a bed for paving bricks and concrete. Some parts of the quarry contained pyrite (iron sulphide) which, on exposure to the atmosphere after crushing, oxidised to liberate sulphuric acid.

This in turn attacked the dolomite, producing magnesium sulphate. Although the upper parts of the wall are protected by the 1980s DPC, action will now be required to conserve the stone below. Always specify sands and aggregates to be free of soluble salts, sulphide mineralisation and other contaminants. Store sands in covered containers on building sites.

Box 3, Figure 22

▶ Ask your State heritage agency for advice on local laboratories that undertake such tests.

Full chemical analysis for both the type and quantity of salts requires carefully controlled sampling and a chemical laboratory with a range of analytical equipment. All the cations and anions (except carbonate) listed in Section 6.1 should be analysed for, using techniques such as ion chromatography for the cations and inductively-coupled plasma atomic emission spectrometry for the anions. Simpler and cheaper (but less accurate) tests are available for both the type and quantity of salts. Test strips (akin to litmus paper) are available from laboratory chemical suppliers and can be used as indicators of the presence of particular salts such as sulphates or nitrates. These strips are only semi-quantitative: they indicate whether there is a lot or a little of the salt present.

The total amount of soluble salt (without distinguishing between the types) can be calculated by measuring the electrical conductivity of a solution of a sample taken from the wall. This is known as the total dissolved solids (TDS) or total soluble salts (TSS) method and is explained in Box 4: *Do-it-yourself salt testing*. Some moisture meters come in a kit which includes blotting paper that is wetted and then pressed onto the wall for a short period to absorb any salt. The meter is used to measure the increased conductivity of the paper.

Another method involves dissolving the salts from a known mass of sample, filtering out the insoluble solids, then evaporating the liquid, leaving behind the salts, which are weighed. These tests are also available from analytical laboratories. Combining TDS testing with the use of test strips for particular salts can often provide enough information for effectively managing a salt damp remediation project.

Ideally, collect samples from mortars rather than bricks or stones, as the mortar is readily repaired and patches on bricks and stones can be disfiguring. Where the mortar is appreciably less permeable than the surrounding masonry, salts are likely to accumulate in the bricks or stones, rather than the mortar. In these circumstances it will be necessary to sample the bricks or stones in order to obtain valid results. Each situation will need to be judged on its merits, the aim being to obtain samples that are representative of the wall as a whole. Record sample locations accurately so that repeat samples can be obtained from nearby to test the effectiveness of later desalination treatments.

Do-it-yourself salt testing

Reasonably accurate determination of total dissolved solids (TDS) can be made by measuring the electrical conductivity of solutions of samples taken from the walls. Equipment required includes sample jars, deionised water, an electrical conductivity meter, good scales that will read to 0.1 gram and a mortar and pestle for breaking down samples to small particle sizes.

A convenient way of obtaining the conductivity meter and associated calibrating solution and sample jars is the 'Salt Bag', a product of the NSW Department of Primary Industries' Wagga Wagga Agricultural Institute, www.dpi.nsw.gov.au/agriculture/resources/soils/salinity/general/salt-bag. While the Salt Bag is intended for monitoring water and soil salinities in agriculture, it can also be applied to salt in walls.

Using an electric drill, collect samples from known depth intervals in a wall (0–10, 10-20 and 20-40 mm are commonly tested, though more may be required if there are salts deeper in the wall). If needed, the samples should be lightly crushed with a mortar and pestle to break up any lumps. Weigh out 5 grams of each sample and add to 50 ml of deionised water. Shake thoroughly and allow a little time for the salts to dissolve. Measure the electrical conductivity of the solution. With aid of the Soil & Water Salinity Calculator supplied in the Salt Bag, determine the salt content of the solution in parts per million. Multiply the result by 10 to account for the initial ten-fold dilution. Convert from parts per million to percent by dividing by 10,000.

Box 4

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12 Good housekeeping

This section is about the basic measures which should always be undertaken to minimise the rising damp 'stress' on the base of walls. These measures may reduce the severity of an existing problem to an extent that major works (such as DPC insertion) are not necessary. Any treatment proposal that does not include or take account of the effect of these measures should be dismissed.

12.1 Maintenance

Figure 23 Maintenance, maintenance, maintenance. Here a roof gutter has rusted through and the colourful green damp zone is due to splash.

Maintenance is important. Too often damp problems are the result of neglect and bad housekeeping: circumstances that can be avoided. Regular maintenance of roof drainage systems, including gutters and downpipes, will involve cleaning gutters and rainwater heads, re-aligning gutters to ensure correct falls towards downpipes, and repairing leaks as soon as they are discovered. Ideally, roof drainage should be inspected during periods of heavy rain so that overflows and other failures can be identified (Figure 23). Are the stormwater systems adequate — are there enough downpipes and are gutters and downpipes of sufficient size?

At the bottom of the downpipes, stormwater shouldn't discharge onto the base of walls, but should flow into a gully basin or sump with an adequate connection to the stormwater system or to a downslope outfall. The gully basin or sump should be big enough to prevent splash, capture all water and permit cleaning or rodding of the stormwater pipe below. There should be ground level inspection points (IPs) on all bends and along long straight runs. The common practice of running downpipes straight into PVC risers prevents access for clearing blockages — such access is essential for good maintenance.

Maintain ground levels around buildings so that the DPC is about 200 mm above ground. This is to ensure that DPCs are not bridged by gardens and paving, and also to prevent rain splash from entering the wall above the DPC. Ideally, ground levels should also be below floor levels. See also Section 12.2: *Site drainage* and Box 2: *Location of damp-proof courses.*

Where a building has timber floors, regular checks of underfloor spaces for fungal rot, borer and termite activity are essential, as they are associated with high humidity, and hence high moisture levels, in adjacent masonry. Rising damp and termite problems often go together.

12.2 Site drainage

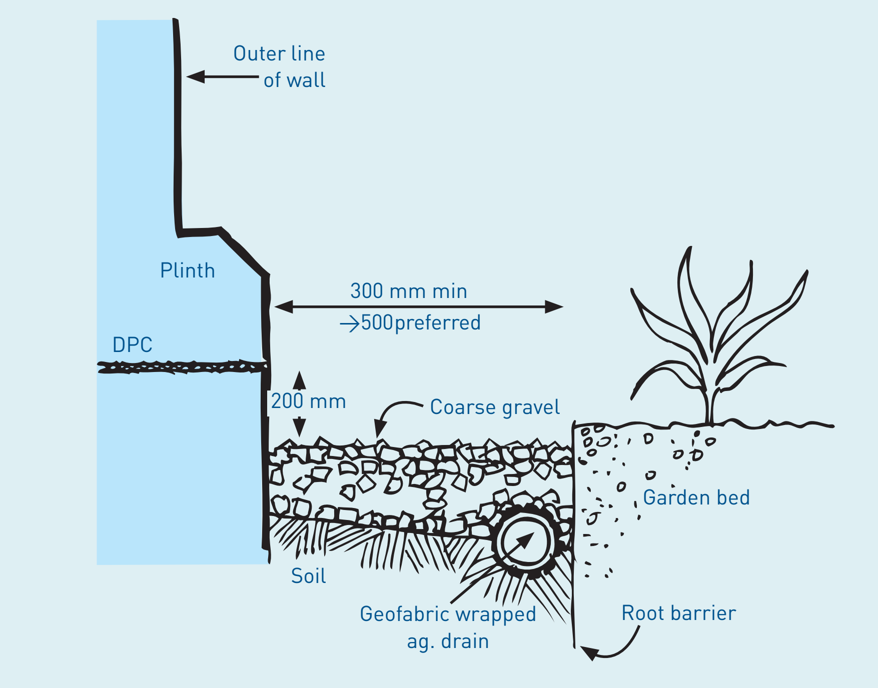
Figure 24 Garden beds against walls almost guarantee salt damp problems. Here the DPC was buried by 300 mm of soil — five courses of sandstone have been severely damaged.

Figure 25 Sterile zone between wall and garden — paved with coarse gravel to allow rainfall in and evaporation out. Drainage is provided by an agricultural drain wrapped in geofabric. Garden sprinklers are replaced with drippers and are kept at least 500 mm away from walls.

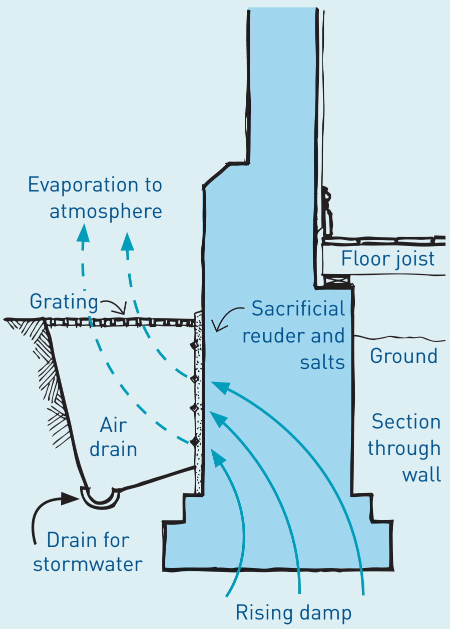
It is important that water does not lie (pond) against the base of walls. Surrounding paths and ground levels should be sloped so as to drain water away from walls: the first metre should have a fall of about 25 mm (1:40) and where possible, the low point should be 1.5–2.0 metres away from the building. A spoon drain at the low point is a traditional and effective way of removing surface water. Though open, it is readily cleaned.

Gardens against walls are particularly bad — soil levels build up as mulches are added, fertilisers contribute soluble salts and watering by enthusiastic gardeners washes it all into the walls (Figure 24). Garden beds should be pulled back and a sterile zone at least 300 mm wide left against the walls. Sprinkler systems should be replaced with drippers and kept well away from walls (Figure 25).

The nature of any paving adjacent to walls is also important. Hard paving contributes to damp problems as it encourages rain to splash up into walls. Further, impervious hard paving will prevent evaporation of soil moisture encouraging it to be transpired via the walls (Figure 28). Coarse gravel is the ideal material for the zone adjacent to old walls as it limits splash from rain while also allowing evaporation of soil moisture (Figure 25). Deliberately permeable paving slabs made of no-fines concrete or resin-bound aggregate offer some potential, although the upper surfaces should be rough and angular to deflect rain strike.



Air drains



Air drains — a possible control measure

Air drains offer some potential to control damp by encouraging evaporation to occur at the lowest possible level. The evaporative zone can be lowered by excavating a trench against the building and exposing the bottom parts of the walls. The advantages of this measure include protecting valuable internal plasters or murals, and reducing underfloor moisture levels. This in turn reduces the risk to timbers from fungal rot, borer and termite attack.

If salt attack is anticipated, a sacrificial render should be applied to the wall face: this is discussed in Section 13. The trench needs good stormwater drainage to prevent ponding against walls. Ideally, the top of the trench should be left open or covered with a metal grating that allows good ventilation and ready inspection of the wall face. While sealing over the top, and providing some means of ventilation is a method of using the space against the walls, it is not recommended because decay could then occur where it cannot be seen or readily repaired.

Air drains are not a new idea: they have been widely used in various forms in the construction of older buildings to provide daylight and to keep basements dry.

Air drains should never be installed in reactive clay soils without geotechnical engineering advice; there is a risk of structural cracking should the soils dry too much (see Box 6).

Importantly, air drains may not work! They will only be successful when the rate of evaporation from within the drain will be high enough to ensure that all drying takes place at that level. This may be impossible in cool damp climates where ground level humidities are high and rising damp climbs several metres up walls. Air drains may only work in hot, dry climates where evaporation rates are already high and where rising damp climbs only a short distance up walls before evaporating.

Further, air drains will not lower damp zones in walls if there are already a lot of salts present. This is because the salt-contaminated zone will wet up during humid periods (due to the deliquescent nature of the salts) and then solute suction (the osmotic pressure of the salt solution) will draw more water towards the highest concentration of salts, effectively adding to the capillary suction and maintaining the rising damp at the present level (see Figure 12). Desalination is essential if air drains are to work (see Section 14: *Removing excessive salt*).

Before installing air drains, consideration should be given to their potential impact on the archaeological resource that may be present adjacent to the building.

Box 5, Figure 26

Ground levels may need to be lowered to expose a buried DPC. This can sometimes be difficult in old city areas, where the progressive build-up of road pavements due to resurfacing has left buildings sitting in low-lying ground surrounded effectively by a levee bank. Air drains offer some potential for lowering the evaporative zone in walls (see Box 5: *Air drains — a possible control measure*).

An in-ground drainage system may be required to lower groundwater levels, or to cut off water running down a slope. A word of caution here. Where buildings are founded on reactive (expansive) clay soils and subsoils, changes to site drainage may upset a pre-existing moisture balance and lead to soil shrinkage and structural cracking of walls as the clays dry out — droughts produce a similar effect. In these circumstances an appropriate treatment might be a compromise between controlling damp and controlling cracking (see Box 6). If wetted-up soils are essential to maintaining stability in the walls then further intervention and additional expense will be needed to deal with the inevitable increase in damp problems. Advice should be sought from a geotechnical engineer if structural cracking due to clay soils is a problem.

The cracking vs. damp compromise

Some soils and sub-soil strata are very reactive to changes in moisture content. They contain clay minerals such as smectite or montmorillonite which expand when wet and shrink when dried with resulting volume changes of up to 50%. These are problem soils for buildings and are commonly associated with structural cracking of masonry walls, particularly those of traditional construction set on flexible footings of stone or brick rather than reinforced concrete. Reactive soil problems can be aggravated by planting large trees with aggressive root systems too close to buildings. Thirsty trees are very efficient at extracting moisture from clay soil, leading to shrinkage and settlement of building foundations, and potentially, substantial damage. The problem is made worse during prolonged droughts.

Geotechnical engineers seek to manage reactive soils by maintaining them in a stable state, the aim being minimal change in moisture content. This is often achieved by the use of impermeable paving around a building, sometimes as a complete concrete apron with integral vertical walls of concrete at the outer limit of the paving. Impermeable plastic membranes are often used instead of concrete and are sometimes also laid beneath timber floors to further limit drying of clay soils. Alternative solutions include in-ground watering systems with automatic controls to maintain soil moisture at a constant proportion.

These solutions almost always mean an increased risk of rising damp and an associated risk of fungal and insect attack to floor timbers. In particular, impermeable aprons around (or under) a building with absent or ineffective damp-proof courses are a guarantee of subsequent damp problems in the masonry walls (see Section 12.4 and Figure 28). The conflicting objectives of minimising soil moisture for damp control, and maintaining soil moisture for crack control, mean that a compromise may be necessary. Where the cracking problem is mild, the compromise may be semi-permeable paving, perhaps coupled with an in-ground watering system. Where the cracking problem is severe and an impermeable apron is the only practical solution, then rising damp should be anticipated and appropriate treatment planned and budgeted for.

Where there is structural cracking due to reactive clay soils, advice should be sought from a geotechnical engineer. That advice should account for any remedial treatment for rising damp that may be required as a result of the need to maintain soil moisture around the base of the building.

Box 6

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12.3 Underfloor ventilation

Figure 27 Semi-circular sections of PVC piping catch salt and other debris from sacrificial plasters and mortars on the walls beneath the floor of a church. Bedded on the same sacrificial mortar mix as that used for the walls, the pipes prevent the recirculation of the salts through the soils below and are cleaned out annually. White salts are visible on the stones in the centre of the photograph.

Maintaining underfloor ventilation is an important part of controlling damp, as it allows ever-present soil moisture to evaporate beneath the floor and to pass out through the vents in the base of the walls. The moisture 'stress' on the walls would be much greater without this ventilation; so would the moisture content of floor timbers, with the consequent risk of fungal rot, borer and termite attack. Mould growth in built-in cupboards can be a sign of insufficient underfloor ventilation.

Dust and cobwebs should be regularly cleaned from vent grilles, and any obstructions, such as paving, planter boxes or dense shrubs, ought to be removed. Make sure that surface water isn't directed through the vents. Before deciding to add new vents, clean out the existing ones and monitor the results for a period, as this may be enough to improve airflow sufficiently. New air vents (matching the original) may be warranted when previous air passages are blocked by changes or additions to a building.

The use of adjustable sliding vent grilles enables reduction of venting in hot dry weather and retention of cool air beneath a house with the added benefit of energy savings. However, they do require an attentive owner to ensure they are not left closed when most needed during cold wet weather.

In cases of bad decay, the vent passages themselves may be totally blocked with debris from decaying masonry. This is partly due to the very function of vents — providing for evaporation — which concentrates drying, and hence salt attack, on the surfaces of the vent passages. In a situation like this, consider lining the passages with rigid plastic liners. Linings may need perforating to allow for the ventilation of wall cavities. It is important that wall cavities should still drain freely; if the linings restrict drainage new weep holes will need to be cut in nearby perpendicular joints.

Controlling evaporation of moisture from sub-floor walls or from adjacent soils is one of the fundamentals of successfully managing rising damp. The emphasis is on control because there can be too much of a good thing. Too much underfloor ventilation may lead to salt attack on the inside faces of walls and on dwarf walls supporting floors. This could lead to unseen damage and could become dangerous. Regular inspection of underfloor spaces is therefore important. Where higher rates of ventilation are needed to manage dampness it may be necessary to apply sacrificial plasters to vulnerable walls (Section 13) and to catch debris from them so that salts are not recirculated (Figure 27).

Changes to floor finishes may be enough to tip the balance towards too little evaporation. For example, an unfinished timber floor may be found to be cold and draughty in winter and so is modernised. Gaps beneath the skirtings are sealed with compressible foam; and new vinyl sheeting, or a polyurethane finish on the floorboards forms an effective seal, reducing previous circulation. New vents may be needed to restore adequate ventilation in this situation.

Remember that underfloor ventilation is also important for reducing the risks of fungal rot and termite attack to floor timbers; a balance must be struck that keeps the timber relatively dry, preferably with a moisture content below about 20% by weight.

12.4 Concrete floors and paving

One of the worst mistakes made by renovators is to remove a ventilated timber floor and replace it with a concrete slab poured on sand or other fill. The concrete and its associated damp-proof membrane (DPM) prevent evaporation, and the soil moisture rising beneath the building becomes focused on the walls. Rising damp problems are almost guaranteed, whereas before there may have been no significant damp, even though the walls may have lacked effective DPCs (Figure 28). This is also the reason why external paving should be permeable.

Concrete floors can cause rising damp

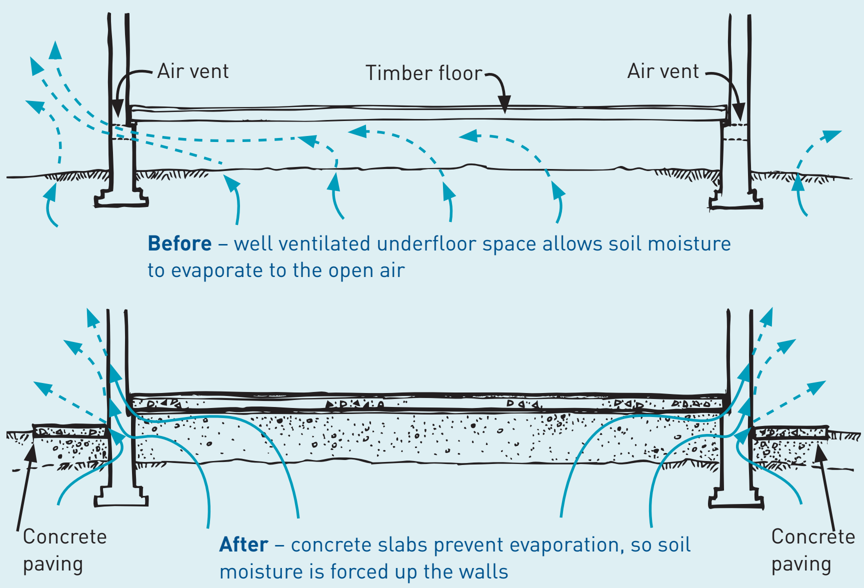

Figure 28

The same effect can often be seen in old houses with tiled or concrete front verandas. Because of absent, bridged or ineffective DPCs, moisture rising beneath the semi-permeable veranda floor is forced up the front wall, causing decay. Very often this may be the only rising damp in the house. Ensuring that roof drainage takes stormwater well away from the veranda may reduce the damp stress on the front wall. However, eventually sufficient salts may accumulate to damage the walls and veranda floor and a more invasive solution will be required. Figure 29 illustrates one such solution, which enables the retention of most of the veranda. Old concrete verandas were laid without a damp-proof membrane (DPM) and are semi-permeable. Replacing such a veranda with a new one laid on a DPM (or sealing the surface of the old one) will add to the moisture stress on the walls.

Verandas and damp

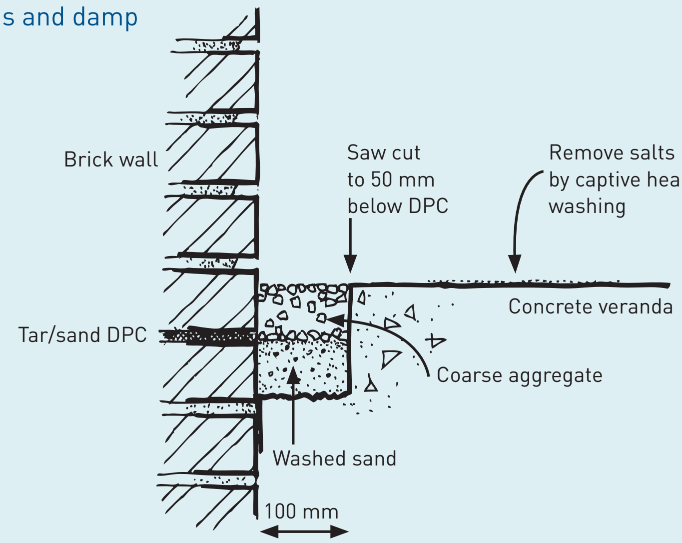

Figure 29

12.5 Repairing a tar and sand damp-proof course

Many tar and sand DPCs decay due to oxidation of the tar, leaving crumbly friable material. Excessive decay endangers the structural stability of the wall and should be repaired. There is little experience with such repairs in Australia and so the following is offered on an experimental basis only.

After raking out the decaying DPC back to reasonably sound material, use a long thin brush to prime the remaining DPC and the joint surfaces of brick or stone with a diluted water-based bitumen rubber material. Use masking tape to prevent spills of bitumen on the face of the bricks or stones. Then use a 'mortar' of the bitumen and well-graded, washed sand in proportions of about 1:2.5–3 bitumen to sand to repoint the joint, compacting tightly with jointing keys (tools) that fit within the joint. If chemical impregnation is also planned it should be undertaken after the repairs to the DPC have thoroughly cured.

13 Treating mild salt damp sacrificially

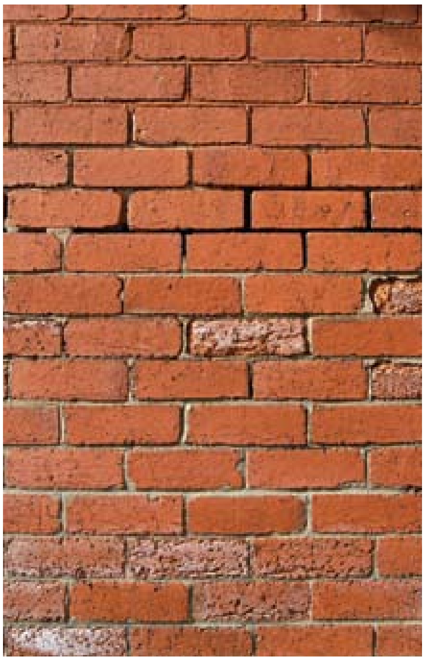

Figure 30 The wrong response to salt damp. Nine courses of brickwork have been repointed in cement mortar, driving the damp even further up the wall and leading to salt attack damage to the bricks. Whereas the original lime mortar was weaker than the bricks and acted sacrificially, the new cement mortar is less permeable, forcing some of the damp to evaporate through the bricks — causing the obvious salt attack decay — and the rest to rise further in the wall. Traditional construction relies on mortars that are weaker than the bricks, partly for the reasons above and also so that any structural cracking will be expressed in the mortar, where it is less obvious and readily patched.

A sacrificial treatment is designed to decay over a period of time, and in doing so, to protect the original masonry. Such treatments use deliberately weak mortars and plasters (or renders) to encourage salt attack to erode the new mortar or plaster rather than the original fabric. They can be useful ways of controlling mild salt damp. Coupled with attention to ventilation, site drainage and the other aspects of good housekeeping, they may limit the decay to such an extent that it becomes a manageable problem that can be lived with — without the need for the expensive insertion of a DPC.

Consider the common case of a building with mild damp in which the lime mortar is decaying from the lower courses of brickwork (the case discussed in *Managing salt attack with maintenance* at 9.4). An all too common (and wrong) response would be to repoint the joints in a hard, dense, cement mortar. This may stop the decay of the mortar, but will transfer the problem to the bricks if they are now the more permeable material. Evaporation will then take place through the bricks, promoting their decay due to salt attack. Alternatively, if the bricks are relatively impermeable, the damp may rise further up the wall and attack the lime mortar higher up. Both outcomes occur in the example shown in Figure 30 — the bricks are decaying and the damp is rising further up the wall. The recommended approach, in which the joints are repointed with a deliberately weak mortar, retains a permeable zone which will continue to decay — but in doing so it protects the surrounding bricks or stones. Because it allows evaporation, it also reduces the risk of the damp rising further in the wall. The salt damp is thus controlled — but not cured — and will require ongoing maintenance. Re-pointing mortar joints is much cheaper and easier than replacing bricks.

The same principle can be applied to plasters or renders. By using weak plasters the evaporative front (and hence decay) is moved from the original masonry out into the new plaster. Provided there is sufficient evaporation from the sacrificial plaster, decay can be limited to the lower parts of a wall. These treatments are the opposite of the incorrect practice of rendering the base of affected walls with dense, relatively impermeable cement renders. This simply prevents the evaporation of moisture, which continues rising up the wall until it can evaporate above the render, starting the problem all over again (Front cover & Figure 54).

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Figure 31 Sacrificial plaster decaying as intended. Plastic sheeting is used to catch the salts and prevent their recycling through the soils and walls.

As they crumble, sacrificial mortars and plasters will produce a dust of sand, lime and salt which should be collected and periodically removed, rather than allowing the salt to re-enter the soil and so be recycled up the wall. When protected from rain strike (internally, in a cellar, or on a veranda) a drop-sheet of strong plastic sheeting can be useful (Figure 31). An alternative treatment, using half round PVC piping beneath a timber floor is shown in Figure 27.

Sacrificial mortars and plasters are designed to crumble and decay and will need ongoing maintenance in the form of periodic patching and, eventually, replacement. Because salts are rarely distributed evenly across a wall, they will decay differentially, and thus require selective patching. Their decay may not be aesthetically acceptable, making them unsuitable for some situations, particularly occupied interiors. More rapid desalination treatments (Section 14) may be needed.

13.1 Sacrificial mixes

The formulation of sacrificial mortar mixes will depend on the particular situation and may vary for different parts of a building. A starting point might be a 1:3 or 1:4 lime: sand mix. If the wall is well protected (such as in a cellar) a weaker mix like 1:5 or 1:6 may be suitable. Where exposed, a sacrificial plaster can be limewashed to provide some additional durability and improve its aesthetics (though take care not use a modern limewash containing resins such as acrylics, as they will prevent breathing: see Section 22). The limewash will fret off with salt attack and so the colour of the sand in the mortar may be important. Re-applying limewash may be the best approach aesthetically.

The performance of sacrificial mortars and plasters can be improved by adding what are known as porous particulates in place of some of the sand. Porous particulates include crushed lightly-fired bricks and crushed porous limestones; their purpose is to provide additional pore space within which the salt can crystallise, thus extending the life of the mortar or plaster. They have a further benefit: their pore space carries water during mixing and application, and that water helps ensure better curing of the lime. There is little experience with porous particulates in Australia and so it is difficult to recommend particular mix proportions. Experiment by replacing half to one part of sand with half to one part of a porous particulate material.

The use of inert short fibre reinforcement has been shown to improve the durability and long term serviceability of some sacrificial renders.

▶ More details about mortars, their materials, mixes and the repointing of joints can be found in a separate document in the same series as this Technical Guide.

14 Removing excessive salt

While sacrificial treatments (coupled with good housekeeping) may be sufficient for many mild cases of salt damp, additional treatments — beyond normal building work — may be needed to reduce high concentrations of salt. Commercially available desalination treatments include: poultices, to actively suck salt from masonry; and captive-head washing, which removes salty wash water with a vacuum system. Researchers have tested electro-kinetic removal of salt, demonstrating its effectiveness in pilot trials. Electro-kinetic salt removal is related to electro-osmotic drying of walls (see Section 16.4).

The decision to proceed to desalination treatments might be made when it is apparent that an otherwise well-made and well-cured sacrificial mortar or render is showing early signs of breaking down after say a year. Rather than waiting until it needs replacing again, it may be better to prolong its life by desalination treatment. In the case of a sacrificial mortar, an advantage of such a treatment is that the bricks or stones are also desalinated, considerably reducing the overall salt load on the mortar.

14.1 Dry vacuuming

Surface deposits of salt (such as those shown in Figures 4, 5, 27, 30 & 50) should be removed using an industrial vacuum cleaner fitted with a brush head. Brushing alone will work, but the vacuum has the advantage of capturing the salt, preventing its recycling through the soils beneath.

14.2 Poultices

Figure 32 Absorbent poultice shortly after application to an interior wall from which plaster has been removed. The poultice is left on the wall until it is dry, which may take 2–3 weeks depending on weather conditions.

Poultices are made of absorbent materials whose fine pore size produces a high suction when in contact with the masonry. Suitable materials include diatomaceous earth and highly absorbent clays such as attapulgite. To these may be added other materials like paper pulp which provides a framework or reinforcing. Poultices are purpose-made by conservators working on sculpture or museum objects. In recent years, a commercial poultice material has been developed in Sydney for use on masonry.

Poultices are applied wet to dryish masonry; the water contained in the poultice soaks slowly into the wall and dissolves salts, while the poultice shrinks onto the wall face (Figures 32 & 33). As the wall dries, water carrying salts in solution is drawn back to the surface by the high suction created by the fine pores in the poultice. The water evaporates and salts precipitate within the poultice, which is left on the wall until it dries out; this may take several weeks, depending on the weather. The poultice is then removed, taking the salt with it. Two or three cycles of poulticing may be required to reduce salt concentrations down to an acceptable level.

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One approach with salty walls is to carry out two cycles of poulticing and then use a sacrificial plaster (Section 13) to control the remaining salts. This method has the advantage of rapid salt reduction with the poulticing, while enabling the sacrificial plaster to last longer — as it has less work to do — improving its appearance over a longer term. Always make sure that the substrate is suitable for poulticing; it may be too fragile or too susceptible to moisture.

14.3 Captive-head washing

These systems use a water jet spray within a hood or jacket which also contains a powerful vacuum to capture the dirty water and prevent it being spread over the masonry. They are used principally for cleaning dirt and grime from walls, and have some potential to remove surface and near surface salts, although there is limited experience with their use for this purpose. They will only ever be partially effective, as they must compete against the initial high capillary suction of the masonry, which will draw some of the water inwards, taking some salt with it.

Captive-head washing may be a useful way of reducing surface salts in bricks and stones prior to sacrificial repointing of the joints. That way the new mortar will have less salt to contend with and should last longer. An alternative would be to use a poultice, which would remove more salt, but which may not be warranted in many cases, particularly given the relative ease and speed of the captive-head washing. The choice will be a compromise between the need to remove salt and the complexity and cost of the treatment.

Other washing treatments have been tried without much success. They have generally been based on a period of spraying the walls with a fine mist, followed by a drying phase to bring the salts to the surface, and then either flushing the salts off with more water, or sponging them off by hand with damp sponges.

14.4 Monitor effectiveness of treatment

Figure 33 A square section of dried poultice has been cut out for chemical analysis. Sampling of the same point during subsequent cycles of poulticing is aided by a marker such as the galvanised nail in the bottom left of the 'window'.

Desalination techniques such as those described will never remove all salts from walls. Although most salts occur relatively close to the surface (because that's where most evaporation happens) there will be some deeper in the masonry which will slowly migrate towards the surface and accumulate there. With time these salts may reach high enough concentrations to warrant a further cycle of poulticing or captive-head washing in order to minimise decay. The results of all desalination treatments should be monitored for their effectiveness over time.

In the simplest cases monitoring might consist of a close visual examination looking for signs of efflorescence, or for early signs of decay of sacrificial mortars and plasters which might indicate the more damaging subflorescence. Inspections should be repeated after a dry spell to avoid the possibility that rain may have washed salts back into the wall just before the first inspection. In larger projects sampling and chemical analyses for salts may be warranted, and should be undertaken before and after desalination treatments.

As well as sampling the masonry for its salt content, poultice materials can be sampled as they are about to be removed from the wall (Figure 33). The results will not be comparable with those from the wall itself but can be used to monitor the effectiveness of poulticing over a series of cycles; later cycles will generally draw less salts, although experience suggests that sometimes the second cycle will draw more salt than the first. While a reduction in salt content will demonstrate the declining efficacy of further poulticing, it will not prove conclusively that the wall has been desalinated: only samples taken from the wall will do that. However, sampling the poultices has the advantage of not damaging the masonry: this may be important, particularly in high-value works such as sculpture.

See Section 11.3: (under *Diagnosis*) for further information on sampling and analysis.

15 Reviewing results before proceeding

This is a review step in the process. It is important to take the time to assess the effectiveness of the treatments to date before more invasive (and costly) work is considered. Have the good housekeeping, sacrificial treatments and desalination measures reduced the damp 'stress' on the walls to the point where they are relatively dry? Is the rate of decay now minimal and not sufficient to warrant further action for the moment? While this may be the case, it is important to understand that periodic desalination and renewal of sacrificial mortars will be required to control the salt damp to this minimal level. Even so, this may be the best outcome, as it removes the need for the more expensive and invasive insertion of damp-proof courses.

As discussed in Section 9.4: *Managing salt attack with maintenance*, there will be many situations where inserting a DPC is an essential part of dealing with a salt damp problem. In the more severe cases this will be obvious from the beginning and for these the intermediate steps of sacrificial treatments, desalination and review can be omitted, and the project can proceed directly to DPC insertion and associated desalination. It is for the less severe cases where the final outcome is less clear that Key Steps 3, 4 and 5 will be of most benefit.

Among things that should be considered during the review is the impact of unusual events, such as storms and floods, which may have temporarily added to moisture levels in walls and floors. Conversely, a long period of drought may lead to an incorrect assessment that the damp has been successfully controlled. There is no substitute for a thorough understanding of the building fabric and its behaviour over an extended period of time.

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16 Inserting a damp-proof course

In many cases of severe damp the only effective solution is the insertion of a new damp-proof course. Done well, it can provide a permanent cure to rising damp to the masonry above the DPC; an important proviso is that salts must also be removed. Regular inspections will be necessary to check that the new DPC is not being compromised by the failure of guttering systems or because of bridging by built-up gardens. Sacrificial mortars used to control salts above the DPC may need periodic maintenance. It may also be necessary to maintain the wall beneath the DPC, using sacrificial treatments or more active salt-removal techniques, such as poulticing (Figure 34; see also Figures 9 and 10 and Box 7: *Potential negative impacts of DPC installation*). Inserting a DPC should only be contemplated after undertaking the housekeeping of Key Step 2 (Section 12).

Figure 34 Stonework below the DPC needs attention as salts accumulate and the mortar and bluestone erode. In the first instance sacrificial treatments should be used to manage the problem. The 1879 ceramic DPC is doing an excellent job of protecting the sandstone above it, although where it steps down the slope it is compromised by hard paving that is laid too high, allowing splash onto the stone (see Box 2: *Location of DPCs*).

The position of the new DPC in relation to ground level and to floor timbers is important; advice on these aspects is given in Box 2: *Location of damp-proof courses* and Section 19: *Inserting chemical DPCs in internal walls*.

New DPCs can be inserted by a range of techniques including:

- **undersetting**, in which sections of the base of a wall are progressively rebuilt in new materials, together with a DPC
- **slot sawing**, where a horizontal slot is sawn through a wall allowing insertion of a sheet DPC
- **chemical impregnation**, where water repellent chemicals are introduced into a wall via a series of drilled holes
- **active electro-osmosis**, in which an electrical current is used to drive water downwards against capillary action.

These techniques are explained in the following sections. Depending on the particular circumstances several DPC insertion techniques might be needed on the one building — all in combination with the management of salts by sacrificial treatments (Section 13) and/or desalination (Section 14).

16.1 Undersetting

Figures 35 and 36 Undersetting to install new damp-proof courses. At left sections, known as pins, are removed from a cavity wall, while at right a pin has been rebuilt on a plastic DPC, the end of which is rolled up ready for use in the next section. In the case of cavity walls, such as at left, the inner leaf also needs to be treated, using one of the methods described in this guide. Where solid walls are being underset, such as on the right, the entire thickness of the wall must be removed and rebuilt to allow a DPC to be installed across the full width of the wall. Partial undersetting of a solid wall is bad practice as the damp will continue to rise through the remaining portion.

The traditional physical means of introducing a new DPC is the technique known as undersetting, or masonry replacement. Undersetting should not be confused with underpinning, which is a treatment for structural cracking due to settlement or footing failure. In undersetting, sections of the base of the wall are removed down to the footing and progressively replaced with new materials and a DPC. Small sections (or pins) of brick or stonework are removed (including all decayed material), leaving pillars to support the wall structure (Figure 35). A DPC is incorporated as each pin is rebuilt; after the new mortar cures the top joint is packed tightly to take up the load of the wall (Figure 36). Adjacent sections are then removed and rebuilt until the whole wall has a new base incorporating a continuous DPC. Figure 37 is an example of undersetting carried out in the 1930s.

Undersetting is skilled work requiring great care. Do not attempt it without specialist advice. Undersetting of high walls may need structural engineering advice. While it may look precarious, the high compressive strength of masonry materials means that the load of a wall can be supported on the remaining brickwork despite the removal of a substantial proportion. In some cases, particularly in thick walls of rubble masonry, it is necessary to provide additional support for the overlying wall while sections are being rebuilt.

Figure 37 Undersetting from the 1930s. New bricks and stones have been inserted up to a line above the window sill on the left. Bricks below the DPC are visibly damp (see also Figure 10).

Though the most expensive, undersetting is the best method for dealing with very severe salt damp because it removes salt-laden masonry as well as inserting a new DPC. No other technique combines both aspects. Additionally, undersetting permits ready inspection inside a wall (whether solid or cavity) which may be important to understanding the extent of decay and the nature of repairs needed (see Section 18: *Cavity walls*).

A disadvantage of undersetting from a heritage conservation viewpoint is that it requires the removal of original fabric. The use of new materials may be more of an issue where good matching to the original is not possible. If the stones or bricks are generally sound and the decay is limited to the mortar, this can sometimes be overcome by dressing off the latter and soaking the stones or bricks in successive baths of fresh water to remove salts, without drying between baths. Conductivity meters can used to show when salt concentrations in the wash water have reached a minimum. The desalinated stones are then rebuilt into the wall together with a new DPC. It is important that skilled stonemasons are engaged to carefully match the appearance of the rebuilt masonry with that of the original wall.

16.2 Slot sawing

Figure 38 Insertion of a DPC by slot sawing. A mortar joint is sawn out with a chainsaw allowing insertion of DPC sheeting. As salt-laden stone is left above the DPC, the technique must be combined with desalination to be successful.

Another physical method involves sawing a horizontal slot through the wall along a mortar joint, inserting a DPC membrane and repacking the joint. Like undersetting, the work is done in stages to ensure adequate support for the wall. Sawing is done by hand with a masonry saw, or with a chainsaw with specially hardened blades. The technique is limited to regular masonry with continuous horizontal courses (such as brickwork) and relatively soft mortars. Dense bluestones and granites will blunt saw blades. Random rubble masonry cannot be cut, though it may be possible to saw-cut a mortar joint if the masonry is in regular courses, or where there is a failed DPC. In thick stone walls where the core often comprises small irregular pieces of rubble, sawing can be impractical, particularly if there are voids with loose stones which may drop into the saw-cut.

DPC sheeting is inserted into the saw-cut, which is then packed with stiff mortar and tightly rammed to take up the load of the walls (Figure 38). After the mortar cures the next section of joint can be sawn out and work progresses around the walls. A potential problem with this method is the perforation of plastic DPCs owing to the (correct) use of sharp sands and the ramming necessary to pack the joint tightly. Thicker (0.75 mm) DPC material is recommended in these cases.

A neat version of this method uses a series of overlapping envelopes made of DPC polyethylene and sealed at the edges. After insertion in the wall, a non-shrink grout is pumped into each envelope in turn through a nozzle on the outer edge. The advantage is that the envelope expands to tightly fill the space left by the saw-cut and so supports the weight of the wall when the grout has cured. Excess envelope material and grout are trimmed off, leaving two DPCs with grout in-between.

The slot sawing method has the advantage over undersetting of reducing disruption to existing historic masonry. By itself, it is an appropriate technique in circumstances where there are no salts in the wall above the new DPC, such as a relatively new building constructed without any, or defective, damp-proofing. **However for older walls, which in Australia will almost certainly contain salt, slot sawing must be combined with sacrificial treatments and/or desalination for it to be successful.**

16.3 Chemical impregnation

Chemical dampcoursing

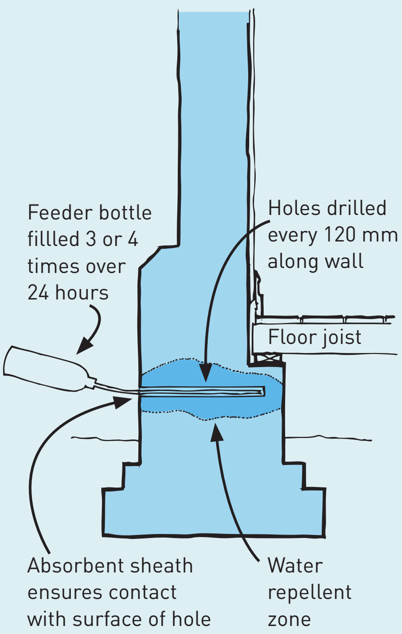

Figure 39 Chemical dampcoursing. Cross-section through a solid wall showing the gravity-fed system. Note that the new water-repellent zone should be installed below all floor timbers.

Chemical impregnation is now the most frequently used treatment for remedial dampcoursing in Australia. The principle is to create a water-repellent zone at the base of walls by inserting appropriate fluids into a series of pre-drilled holes. The fluid permeates through the pore structure of the masonry, meeting fluid from the adjacent drill holes and curing to form a continuous water-repellent zone. Such treatments have been used in Australia for about thirty years. In the UK, where they been used for fifty years, there is a British Standard which gives recommendations for the procedures to be used in diagnosing and treating rising damp by chemical methods (see *Further reading*).

A range of chemicals has been used for this purpose, the most common today being alkyl and alkoxy- siloxanes (commonly shortened to siloxane) which are carried in an organic solvent at a rate of about 5–7% by weight. Following impregnation, a catalyst in the fluid triggers the formation of a gel, the solvent evaporates and a water-repellent silicone resin is left lining the pores of the masonry. The treatment will prevent rising damp but will not stop water under pressure, so impregnation techniques cannot be used where there is a hydrostatic head such as may occur when tanking a cellar or basement.

Other chemicals used include aluminium stearates and potassium and sodium siliconates, but their use has declined in favour of siloxanes.

Water-based versions of silanes and siloxanes have been developed in response to concerns about health issues associated with volatile organic solvents. These materials are emulsified as viscous 'creams'; they have a relatively high concentration of active ingredient and a small proportion of water as carrier. They are comparatively new on the Australian market and there is limited experience with using them. Early indications suggest that there is some variation between products.

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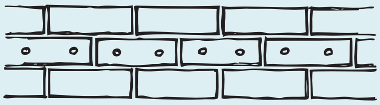
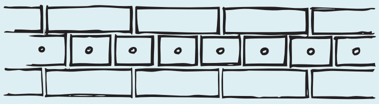
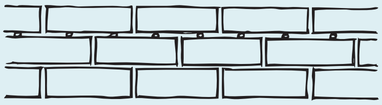
Drilling patterns



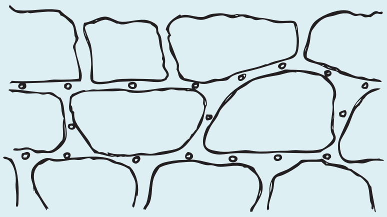
Drilling pattern for stretchers



Drilling pattern for headers



Drilling pattern for mortar joints



Drilling pattern for dense rubble stonework

Figure 40 Drilling patterns for chemical impregnation. The first two examples are for low-pressure injection into the bricks and the last two for treating the mortar joints by either low-pressure injection, gravity-fed fluid, or water-based cream. Where a wall 230 mm (one brick) thick is to be injected, a header course should be drilled for preference. Where a stretcher course is to be drilled the stretchers on the other side of the wall must also be drilled, either from the other side, or from this face in sequence — by drilling and injecting the visible stretchers first and then drilling through the same holes to the other stretchers and injecting them in a second phase. The same sequential approach is applied when cavity walls are accessed from one side only.

Holes about 10–15 mm in diameter are drilled about every 120 mm in a line along the base of a wall, such as in a mortar joint. In bricks, two holes are drilled in every stretcher and one hole in every header (Figure 40). The holes are drilled to within about 30 mm of the other side of the wall or brick (Figure 39).

Where the masonry consists of hard and dense rubble stonework, it may be impractical to drill into the hard stone; and penetration of dampcoursing fluid into dense materials may be imperfect. The rubble construction means that there is a lot of mortar with potential for voids. In these circumstances some suppliers advise enveloping the dense material with dampcourse fluid through holes drilled into the mortar above, below and to the sides of each stone (Figure 40). Thick walls of irregular rubble may be difficult to fully impregnate.

Fluid is delivered into the holes by either a tube or a lance depending on whether it is to be gravity-fed or injected under low pressure (Figures 41 & 42). The choice of technique is to some extent determined by the nature of the masonry: gravity-fed diffusion is suitable for porous mortars and soft bricks, while normal bricks can be injected under low pressure (20–70 psi, 150–500 kPa). High pressure injection (greater than 150 psi, 1000 kPa) risks the blowout of weak mortars and imperfect coverage in sound materials due to viscous fingering, a process in which the fluid advances as a series of fingers, leaving gaps between.

Water-based creams are delivered by a cartridge or caulking gun fitted with a narrow tube that reaches the rear of the holes. Creams are generally applied to mortar joints, as the more porous mortar permits better diffusion and penetration of the emulsion.

Critical to the success of any chemical treatment is the formation of a continuous water-repellent zone through the entire wall thickness. This may be difficult to achieve and must be judged by the operator, whose experience and skill are essential to a good result.

Each of the three techniques described:

- low pressure injection of solvent-based fluid
- gravity-fed diffusion of solvent-based fluid
- diffusion of water-based cream

permit prolonged or multiple applications of fluid or cream, which allows the operator to add more if there is any doubt about the adequacy of coverage.

Figure 41 and 42 Chemical impregnation. On the left: the gravity feed system in which small plastic bottles are filled with a lance. Depending on the nature of the masonry and thickness of the wall the bottles are filled three and sometimes four times. Open holes just above the drilled line are used to indicate extent of penetration. On the right: low-pressure injection in progress on an interior wall from which plaster has been removed. Note the variation in the permeability of the brickwork; the brick on the left is already saturated and the lance is moved on while the central brick slowly fills with fluid.

The following should be considered when contemplating a chemical DPC:

- chemical impregnation should not be attempted where the mortar or masonry is weak and crumbling: treat only relatively sound materials
- voids in thick walls may lead to loss of fluid. Where voids are large, it may be necessary to fill them with grout prior to chemical impregnation (grouting may be desirable anyway to re-establish the integrity of the wall). This needs to be evaluated prior to commissioning any treatment
- in a small proportion of cases the chemistry and mineralogy of the substrate may affect the curing and water-repellency of the fluid or cream
- very wet walls may limit diffusion of gravity-fed fluid or cream
- for the treatment to be successful the wall must be allowed to dry thoroughly after impregnation, particularly during winter months
- good operators may use more fluid than might otherwise be necessary in order to be certain of thorough penetration through the full wall thickness
- dampcoursing fluid and creams are expensive and so there is a cost pressure on contractors to use less
- unscrupulous contractors might dilute the fluid with additional solvent, leading to insufficient water-repellency, or space the drill holes at wider intervals than recommended leading to incomplete coverage
- injection of fluid may displace saline moisture in the wall, forcing it higher up, where it may cause decay to susceptible materials not previously damaged. It is advisable to use a desalination poultice at the same time as the injection
- never drill and impregnate directly into an old tar and sand DPC — it may not be working well, but perforating it will not help

- the solvents used may dissolve polystyrene insulation in cavity walls; and may dissolve tar or bitumen from existing DPCs and spread it through the masonry, leaving a brown stain on the surface
- fumes and fire safety issues with solvents must be managed
- the position of the chemical damp-proof zone in relation to ground level and to floor timbers is critical to achieving a good result. See Section 19: *Inserting chemical DPCs in internal walls* and Box 2: *Location of damp-proof courses* for important advice on these aspects
- chemical impregnation treatments can be used in the zone below existing DPCs. This may be useful where the existing DPC is too far above ground level (see Box 2: *Location of damp-proof courses*), and/or where reducing evaporation to the exterior (and therefore transferring it to the underfloor space) is an appropriate solution
- the treatment may leave a row of unsightly plugged holes; when filling them, care is required to accurately match the surrounding material.

▶ See Section 6.1: *Which salts?* for an explanation.

Importantly, chemical impregnation provides only a barrier to rising damp; it does not prevent salts in the walls above the new damp-proof zone from cycling in and out of solution with changes in humidity, and so continuing to cause damage. **Chemical impregnation must be combined with sacrificial treatments and/or desalination for it to be a successful treatment for salt damp** (Figure 43).

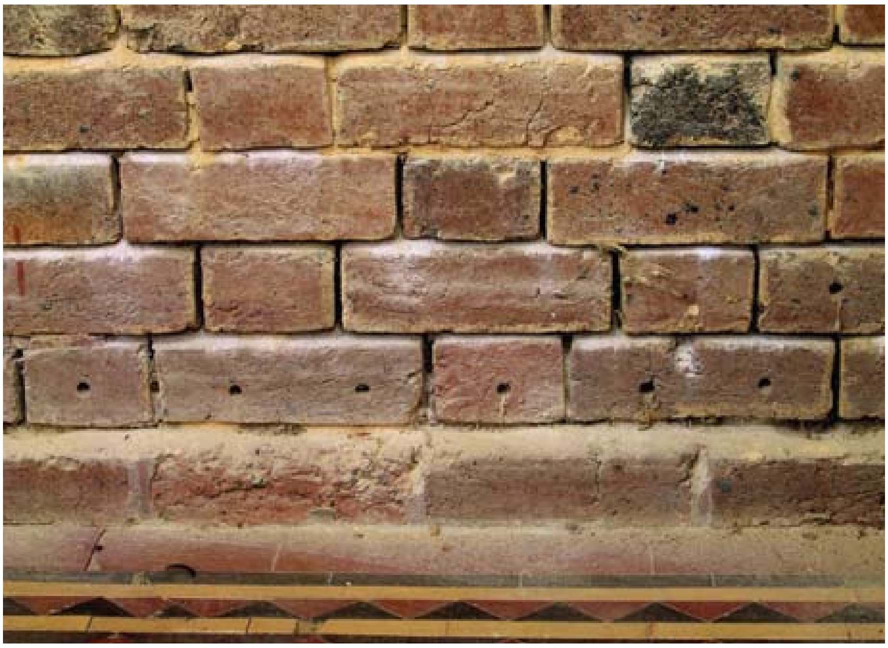


Figure 43 Despite chemical impregnation, decay continues to the brickwork above the treated zone. This is because salts remain in the wall and can cycle in and out of solution with changes in humidity, causing ongoing salt attack decay. The yellow sand is what remains of a sacrificial mortar applied at the time of chemical impregnation. The white material is a mixture of the original lime mortar and salt. Further treatment should include raking out the salty mortar and repointing in a sacrificial mix and possibly poultice desalination, together with an assessment of the effectiveness of the chemical DPC. Note that extensive repointing may bridge the DPC, and so it may need re-treatment once the new mortar is well-cured. Alkaline-stable damp-course fluids should be used.

16.4 Active electro-osmosis

Electro-osmotic damp-proofing is based on the scientific observation that water moving through a porous medium creates an electrical potential difference which is known as the 'streaming potential'. By using an active current to superimpose an electrical potential, water can be driven in a chosen direction. This is exploited in various ways including the dewatering of wet silts and clays to allow the excavation of construction sites.

Both passive and active approaches have been used in applying electro-osmosis to the treatment of rising damp.

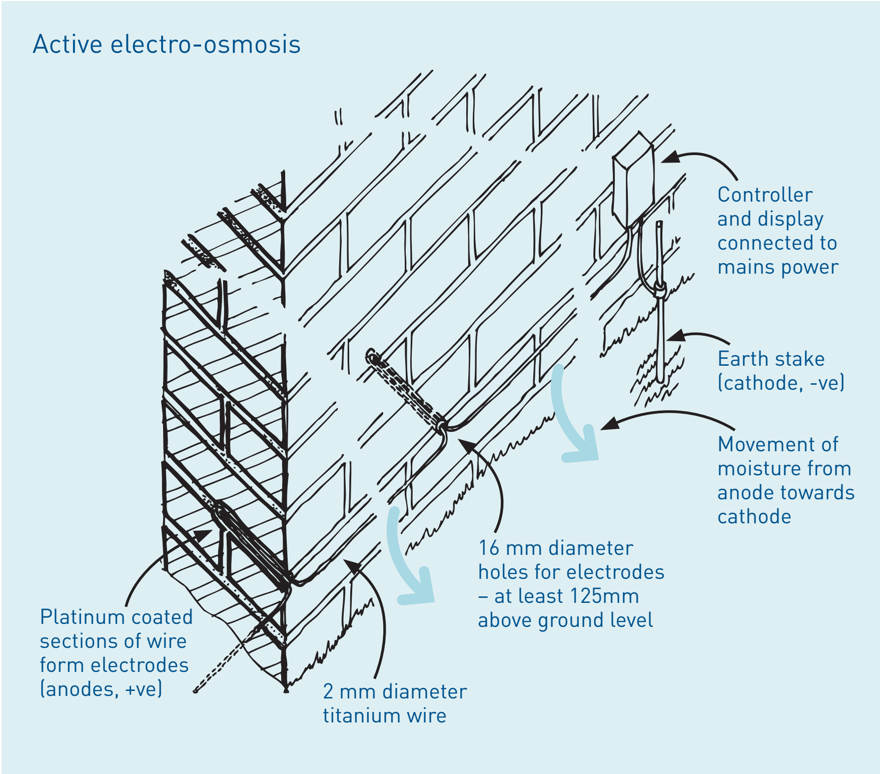
Passive electro-osmosis was widely used across Australia in the 1960s and 70s and gained a notorious reputation on account of the many failures of the technique. Most claimed successes can be attributed to other works undertaken at the same time, including repair of gutters and attention to ventilation and site drainage. Proponents of the method argued that by electrically connecting the damp zone of the wall to the ground, the electrical potential could be negated and the moisture flow stopped. A continuous copper strip was looped into holes drilled into walls and laid into a raked-out mortar joint (or left behind skirting boards) about 300 mm above ground level. The copper strips were earthed to the ground to complete the circuit.

There is no scientific basis to the passive system — it is the movement of water through the porous medium that creates the electrical potential, not the other way around, and so simply earthing the resulting charge will not prevent the damp from rising, as capillary suction is unaffected.

On the other hand, **active electro-osmosis** is based on applying an active DC current to drive water down a wall in a similar manner to its use for dewatering building sites. Although the technique was available in the 1960s it was not much used due to the cost of electricity and because the copper strips (or electrodes) were rapidly corroded in salty walls.

In recent years a more advanced version of active electro-osmosis has been introduced to Australia from the United Kingdom. This system uses titanium wires with platinum-coated electrodes to overcome the corrosion problem. It has an electronic controller that reduces power consumption to a minimum and has a display that enables monitoring of voltage and current (Figure 44).

Figure 44 The active electro-osmosis system showing arrangement of electrodes. The platinum-coated sections of titanium wire that form the anodes are looped into holes drilled in the wall approximately one metre apart and are set in a rich cement mix to form an electrical contact with the surrounding masonry.



The following should be considered when contemplating active electro-osmotic treatment of rising damp:

- the system must remain switched on at all times
- later building works may cut through the cables, though the risk is reduced by running the cables in continuous loops
- there are no chemicals such as organic solvents involved in the process
- the system has received a current CSIRO Appraisal (see Further reading) indicating it "is suitable for counteracting rising damp in new and existing buildings", though similar 'fit-for-purpose' assessments have not been made by the UK Building Research Establishment (BRE) or the British Board of Agrément (BBA)
- electro-osmosis requires a material that has high surface charges and fine pores, such as old underfired bricks. Treatment of materials such as limestones with large pores is unlikely to succeed
- there are some concerns as to its function at low moisture levels when the transport of water as a liquid ceases and is replaced by evaporation and condensation of vapour. At very low moisture levels this may not matter
- because active electro-osmosis dries the wall below the line of electrodes it has the potential to protect floor timbers, even though the electrodes may be installed at, or just above, floor level (see Section 19: *Inserting chemical DPCs in internal walls*)

- active electro-osmosis may be useful as a supplementary damp-proof course where the existing DPC is too far above ground level (see Box 2: *Location of damp-proof courses*)
- stray currents may cause corrosion of steel reinforcing in concrete and of pipes and other buried metals
- the effectiveness and long term performance of active electro-osmosis in very salty walls is unclear.

As noted in Section 14 *Removing excessive salt* there is a related phenomenon, electro-kinesis, which is being investigated as a possible means of desalinating walls. The interrelationship between electro-osmotic dewatering and electro-kinetic desalination warrants further investigation.

While active electro-osmosis may remove salt already in solution below the electrodes, there remains the issue of salts above the electrodes which are free to continue causing damage with changes in humidity. **Like chemical impregnation and slot sawing, active electro-osmotic damp-proofing must be combined with sacrificial treatments and/or desalination for it to be a successful treatment for salt damp.**

Potential negative impacts of DPC installation

Installing a DPC in a wall may reduce the evaporative zone on the external face from a height of about 1000 mm down to about 200 mm. This means that moisture evaporation through this zone will be increased by a factor of five times, assuming that evaporation from all other wall surfaces is unchanged. This has implications for the masonry below the DPC, which may begin to decay rapidly as a result and may require additional remedial treatments such as desalination.

Two treatments might be considered in this situation. By chemically impregnating all of the exposed masonry from ground level up to 200 mm, a new DPC can be installed without leaving an evaporative zone below it. Secondly, active electro-osmosis may keep the zone above ground level dry. High salt concentrations should be removed from this zone prior to the use of either chemical impregnation or electro-osmotic treatments.

Alternatively, where both salt levels and rates of evaporation are relatively low (and where the site is well drained) it may be appropriate not to install a DPC but to manage the ongoing salt attack and rising damp using sacrificial treatments and minimising the rising damp 'stress' on the walls. This will mean that evaporation (and hence decay) will continue to occur over a broad zone, but will be much less intense; so the rate of surface loss will be lower at any one point than it would be if the zone were to be narrowed.

Also note that where installing a DPC reduces evaporation the risk of fungal rot and insect attack to floor timbers will be increased, due to higher humidities in the underfloor space.

Box 7

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17 Desalinating walls

The works of this last of the Seven Key Steps are similar to those of Key Step 4 (Section 14: *Removing excessive salt*) which should be referred to for details. The works consist of two or more of:

- dry vacuuming
- poulticing
- captive-head washing
- sacrificial treatments.

They are undertaken in combination with the insertion of a DPC; the focus is on removing as much salt as possible from above the new DPC.

Desalination may be needed in combination with all of the methods of DPC insertion. Even with undersetting there may be a need for desalination: particularly where costs and/or a shortage of matching replacement materials limit the height up to which undersetting is carried, and so desalination is needed to manage salts that remain higher in the walls. With chemical injection it is useful to begin poultice desalination prior to injection, as explained in Sections 16.3 and 21. Where electro-osmotic damp-proofing is to be used, remove as much salt as possible prior to switching on the current.

Despite thorough desalination there will still be the need for annual monitoring for further salts migrating to the surface from deeper within the walls. Follow-up desalination and sacrificial repointing may be required until most salts are removed from the masonry. Monitoring may reveal a localised area of dampness indicating a 'leak' in the new DPC which may need remedial injection or other corrective action. In addition there will always be the need for maintenance of the wall between the DPC and ground level; this will commonly require the use of sacrificial treatments.

Building Code of Australia

The annually updated *Building Code of Australia* (BCA) is a uniform set of performance-based technical provisions for the design and construction of buildings and other structures throughout Australia. The BCA contains mandatory Performance Requirements accompanied by optional Deemed-to-Satisfy Provisions. In relation to rising damp the BCA provides Deemed-to-Satisfy Provisions for:

- acceptable damp-proof course materials;
- location of damp-proof courses; and
- ventilation of sub-floor spaces.

The BCA details minimum requirements for building work and is given legal effect by building regulatory legislation in each State and Territory. It is generally applied to new buildings and new building work only. Application of the BCA to new work on existing buildings is triggered when the scale of works reach certain thresholds that vary between States. In some States it may be necessary to bring an entire building into compliance due to the extent of construction work, irrespective of whether work is being conducted in that area. When works to an existing building are only repairs (such as remedial damp-proofing) then the BCA is not called up, though it provides a useful reference as a construction standard. The Australian Building Codes Board is currently (2008) considering issues related to salinity, that may result in changes to the BCA.

Box 8

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18 Cavity walls

Figure 45 Decay of an inner leaf of brickwork into the cavity. This would not have been discovered had the wall not been opened up for undersetting of the outer leaf. The decay means that evaporation is occurring in the cavity in preference to the interior of the house. Multiple paint coatings or previous repairs of interior plasters with dense impermeable materials may be an explanation. Whatever the cause, the implications of decay occurring where it cannot be seen are profound. The inner leaf must be treated, using one of the methods described in this guide.

Prior to the late nineteenth century all brick and stone walls were of solid construction, although thick stone walls may have consisted of two leaves with a rubble-filled core that often contained voids. Solid walls, particularly those made of 230 mm (nine inch) brickwork are susceptible to moisture penetration during prolonged driving rain. The cavity wall was developed in response to this problem and became the dominant twentieth century means of domestic building until the advent of brick-veneer construction.

In domestic construction cavity walls generally consist of two leaves of brick 110 mm (4.25 inches) thick with a 50 mm (2 inch) cavity. Metal ties are built in at regular intervals to bind the two leaves together. Cavity walls stay dry on the inside because any moisture that penetrates the outer leaf runs down the cavity and out through weep holes left in perpendicular joints at the base of the wall. Critical to their success are the correct detailing and use of flashings and the care taken in construction to prevent mortar droppings (snots) from accumulating on the wall ties, and so providing a moisture bridge across the cavity. A pattern of "dots" of moisture on an inside face can be a sign of a cavity bridged at the wall ties.

Salt damp can be particularly problematic in cavity walls because of the risk of decay inside the cavity where it cannot be seen (Figures 45 and 46). In normal circumstances most decay should occur at the external surface of the wall (because that is where there is most evaporation — see Section 9.1: *Factors causing salt attack*). Some decay can be expected on interior surfaces, particularly if the rooms are heated and air-conditioned.

Unfortunately, 'normal' circumstances are progressively removed as successive owners seek to deal with a damp problem by sealing it in. Hard waterproof plasters and multiple paint coatings on interior surfaces; and dense cement renders, cement repointing of joints, as well as paint coatings on external surfaces; all reduce evaporation from these surfaces and increase the likelihood that evaporation inside the cavity will become dominant, leading to unseen decay.

While Figure 45 shows an example of decay of an inner leaf, more severe decay is likely on the inside face of an outer leaf, as shown in Figure 46.

Despite repointing with hard mortars, water will enter the wall through the bricks and through cracks between the new mortar and bricks as well as through failed DPCs. And if walls have been sandblasted they will be particularly liable to water penetration as both bricks and mortar will be much more permeable than before. Where the bedding mortar was relatively weak (because it was to be finished in a stronger pointing mortar) it will be susceptible to rapid decay into the cavity.

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Severe decay of the outer leaf will lead to the accumulation of debris at the bottom of the wall, bridging the cavity with saline material and causing dampness inside the building. Wall ties will be more susceptible to corrosion in the saline environment and ultimately the outer leaf will become structurally weak — all of it unseen from the outside. Buildings close to the coast will be particularly at risk of this type of damage from sea spray.

When inspecting damp problems in old buildings with cavity walls it is essential that the inside of the cavities be checked for decay, bridging and the corrosion of wall ties.

Inspection of cavities will often involve removal of vent grilles, and removal of bricks at corners to get a clear sighting along the cavity. Borescopes, industrial versions of medical endoscopes, use fibre optics to enable viewing through narrow holes drilled through mortar joints. They are commonly used to detect mortar snots on wall ties. Because they involve minimal intervention they can be useful tools for determining the need for further opening up.

Repair of an outer leaf that is found to be decaying into the cavity may involve its progressive removal and reconstruction using the undersetting technique described in Section 16.1. If the decay is only to a weak mortar then the bricks can be soaked to remove salt and reused in the wall. A new DPC should be inserted at the same time. Even if repair of the outer leaf is not (yet) warranted, the bottom of the cavity should always be cleared of debris.

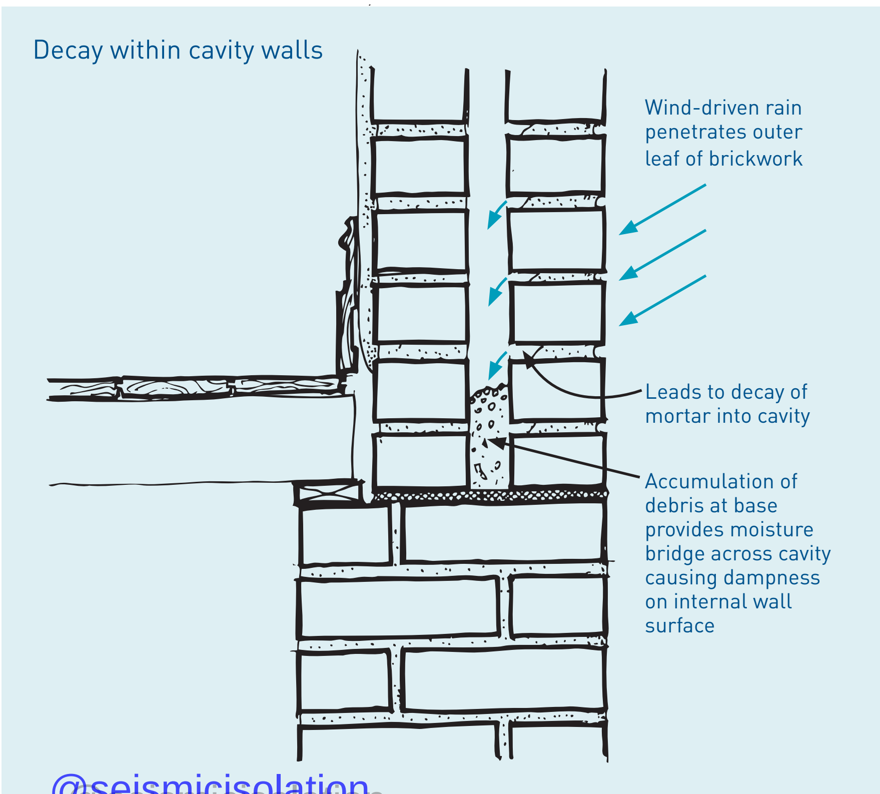


Figure 46 Section through a cavity wall showing deterioration of the inside face of the outer leaf due to moisture penetration through the brickwork. Such decay is more likely where the wall has been sandblasted, making the outer surface more permeable, and where the DPC is not effective, allowing rising damp to compound the problem. Even with a perfect DPC, decay into the cavity may be a problem, particularly near the coast where sea spray carries salt into walls.

19 Inserting chemical DPCs in internal walls

A common practice when chemical dampcourses are being installed in internal walls is to remove the skirting boards and plaster and to drill into a course of bricks just above floor level, as shown in Figure 47. It must be understood that this is a compromise between the good practice of installing the DPC as low as possible on the one hand, and minimising cost and disruption to the building owner on the other. While the new DPC will protect the overlying masonry, wet bricks will remain below in contact with floor timbers, with the consequent risks of fungal rot, borer and termite attack.

It is bad practice to cut costs and minimise disruption by drilling at a steep angle from above skirtings which are left in place. When salt damp is severe enough to warrant DPC insertion, skirtings should always be removed and their backs inspected, as they may be damaged by rot and termites.

As shown in Figure 47 the desirable location for the DPC is below all floor timbers. This is because the purpose of the DPC is not only to keep the masonry dry but also to keep the floor timbers dry. Unfortunately, in many Australian houses the DPC was not carried through under the floor plates; instead, the latter often sit directly on masonry, which may be quite damp.

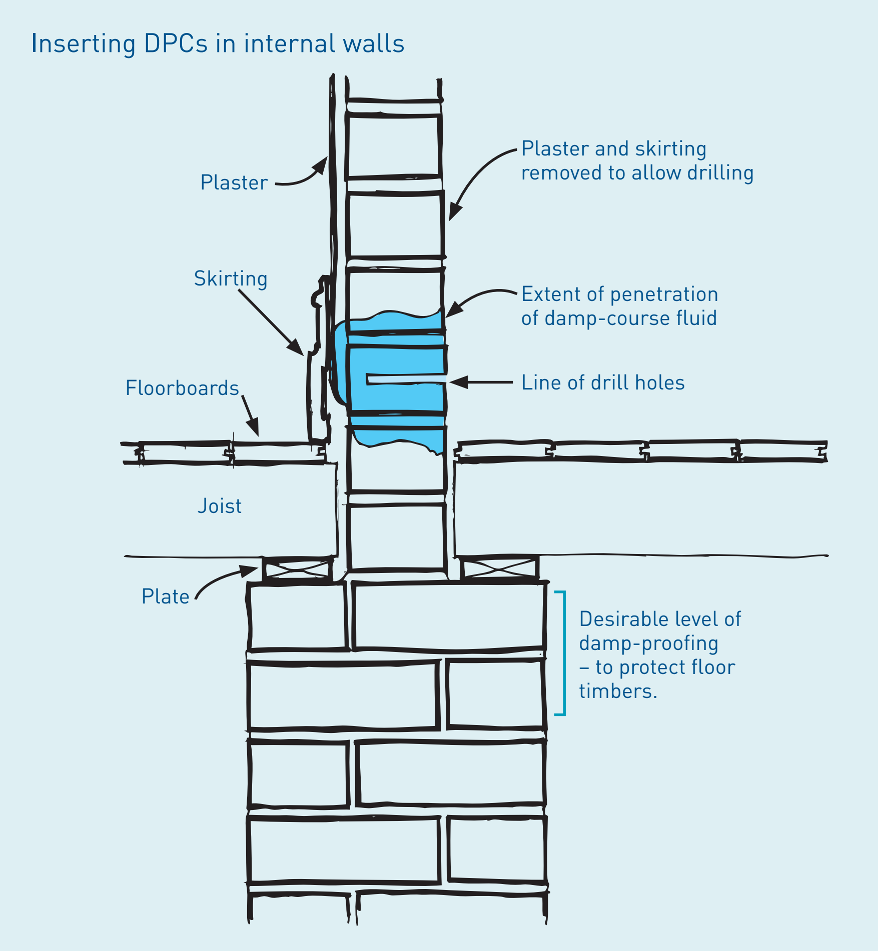
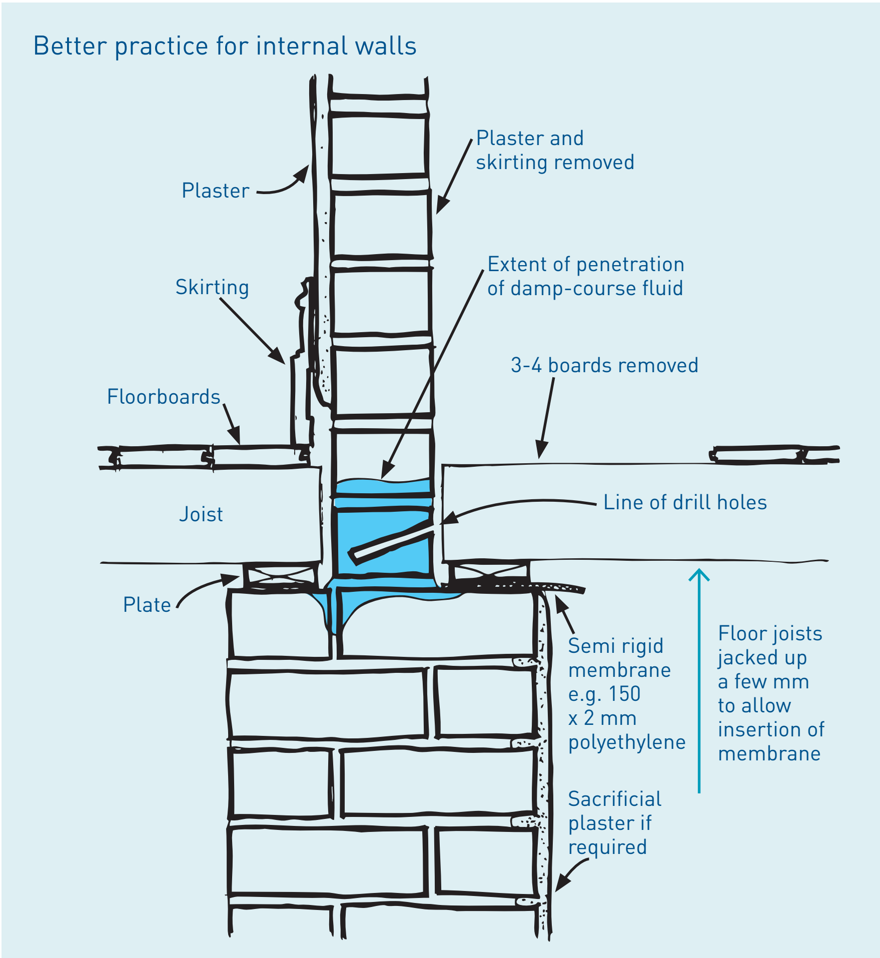


Figure 47 A common practice when installing chemical dampcourses into internal walls is to drill and inject the course of bricks shown. This produces a water repellent zone that may protect the wall above but does not protect the floor timbers, which remain at risk of fungal rot and termite attack.

Best practice DPC insertion would therefore require the removal of sufficient floorboards to enable working access to the wall so that it can be injected (or slot sawn) below floor level. This will obviously add to the expense and disruption of the job. (Note that there are practical difficulties with injecting the upper course or slot sawing in the first mortar joint below the floor plate, as the upper course of bricks will be loosened by vibration. Drilling, or slot sawing, would need to be in the second or third course or joint, respectively.) There may be additional complications if the wall below floor level is not made of regular brickwork but of dense stone such as bluestone or granite, which may make DPC insertion difficult. A less expensive alternative, but one which would still provide protection to both masonry and timber, is explained below.

Three or four floorboards are removed to enable the drilling and injection of the course of bricks immediately above the floor plates as shown in Figure 48. Dampcourse fluid will penetrate up into the course above and downwards into the top of the wider masonry below.

Figure 48 Proposed method of achieving damp-proofing of interior walls and of floor timbers using a combination of chemical impregnation and insertion of a semi-rigid membrane beneath the floor plates. The membrane, which might be 2–3 mm thick polyethylene, such as is used for root barriers and lawn edging, is pushed in hard against the newly created DPC. Removing floorboards, which is a skilled activity requiring a carpenter, may not be necessary if there is access and working room beneath the floor.



The mortar joint immediately above the wider masonry (and directly below the brick being drilled) is where we would expect to find a DPC. A partially effective DPC (e.g. of tar and sand) at this joint will limit downward penetration of the fluid. Drilling and impregnating an existing tar and sand DPC would be counter-productive and should never be undertaken. Impregnation adjacent to a tar and sand DPC creates the risk of staining as solvents in the fluid dissolve components of the tar, although this shouldn't be an issue for interior walls that are to be replastered.

Protection of the floor timbers is achieved by jacking floor joists up a few millimetres to enable insertion of a new membrane beneath the plates. The membrane can function as both a DPC and as a partial termite shield, though it could not be considered as termite shielding within the meaning of Australian Standard AS 3660—2000: *Termite Management*.

Appropriate materials might be stiff plastic such as is used for root barriers and lawn edging. Normal DPC material, whether 0.5 or 0.75 mm thick, would not be suitable, as it would not resist the abrasion of dry insertion, nor have sufficient rigidity to enable it to be forced into place. A material of the order of 2–3 mm thick would be more suitable. Standard termite shield materials, such as galvanised steel and other metals, are not recommended, as they may corrode in the damp saline environments that are commonly encountered in old walls.

Floor plates on dwarf walls should also be protected with a membrane.

Instead of chemical impregnation, internal walls might be treated by undersetting, in which case it is important that the new DPC be carried through under the floor plates.

Whichever treatment is used, it may be desirable to apply a sacrificial plaster to the face of the wall below the new membrane. More thorough desalination will be required for very salty walls, such as that shown in Figure 50.

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20

Out of sight, out of mind: the need for improvements to practice

Figure 49 The photograph at right is looking beneath a floor against a damp wall, and shows a wet zone on the timber joist and plaster debris on the floor plate, which is wet and rotten. The diagram below is a sectional view showing how the plaster debris drops behind the floorboards and sits on the floor plate. The debris provides a path or bridge around the DPC. Even though the DPC may have been only partially effective, the newly created bridge will add to the rate at which damp rises. And the salt that caused the first plaster to fail is being recycled into the wall where it will cause more damage. Furthermore, the plaster debris holds moisture against the floor timbers, increasing the risk of fungal rot and insect attack.

The risk for many walls and timbers in underfloor spaces is that they are unseen and ignored, as these photographs show. Figure 49 was taken through a floor trap near a damp wall and shows a wet zone on the floor joist. Of particular concern is the pile of debris sitting on the floor plate to the left of the joist. The debris is from the previous plaster on the wall above, plaster that decayed with salt attack, some of it falling behind the skirting board and onto the plate. Most of the debris on the plate would have landed there during the last round of repairs when the damaged plaster was hacked off the wall, some of it falling through the gap between floorboards and the wall itself as the diagram shows. Being salt-laden (and hence hygroscopic) the debris attracts moisture and spreads it to the timber plate and the joist. After removing the debris, the wall plate beneath was found to be mostly rotten, with little sound timber remaining. As well as promoting fungal rot, high moisture levels in timber significantly increase the risk of borer and termite attack.

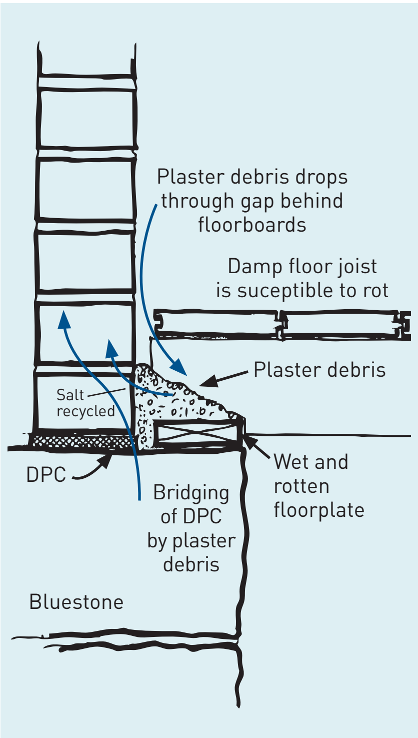

Figure 50 shows a similar view beneath the floor of another house. Salt attack is decaying the brickwork and the debris is accumulating on the damp floor plate. The brick debris overlies previous plaster material which has fallen onto and behind the plate, thereby making a bridge across the DPC which is located out of sight, directly behind the floor plate. Unfortunately the plate is not isolated from the damp masonry below, a situation that is common in Australian buildings. Note the extensive salt efflorescence on the face of the bluestone rubble.

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Figure 50 Looking beneath a floor at the edge of a debris-covered floor plate. There are water stains on the end and base of the joist. Salt attack is damaging the bricks at the rear, which are slowly crumbling onto the floor plate. Dense salt crystals encrust the surface of the rubble bluestone in the foreground. The lack of a membrane beneath the floor plate means that the floor timbers are at greater risk of fungal rot and termite attack.

The problem of accumulation of plaster debris on floor plates is widespread and is likely to be encountered wherever repairs to plasterwork have been undertaken.

The message from these photographs is that plaster repairs to the walls above are endangering the floor timbers below — timbers which may be out of sight and out of mind to the damp-proofing contractor. There is a need to change the work practices of specifiers and contractors to recognise and deal with these risks. There are five key points to keep in mind:

- all investigations of buildings for salt attack and rising damp should include an underfloor inspection to assess the condition and risks to floor timbers, in addition to the state of the walls, and any dwarf walls that support the floor
- all debris accumulating on floor plates should be removed (e.g. by industrial vacuum cleaner) which will mean access to the floor plate — either from under the floor where headroom is sufficient; or by lifting floorboards against the wall; or from the other side of a wall that is being opened up for undersetting
- membranes should be inserted beneath the floor plates to protect them from dampness coming directly from the wet wall below — see Section 19: *Inserting chemical DPCs in internal walls)*
- replastering work should include additional measures to prevent debris from dropping through the gap behind floorboards and to retrieve any that does
- certification of completed works should include underfloor inspections to confirm that debris has been removed from floor plates and that all floor timbers are suitably protected from rising dampness.

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21 Repairs to interior plasterwork

Figure 51 Discoveries on removing plaster from interior walls. On the left, the brick-on-edge is a partial undersetting of the inner part of a solid wall, leaving the outer part untreated — a total waste of effort. On both walls, but more apparent on the right, are remnants of a dense hard cementitious material containing milled iron that was designed to rust and block pores, making it impermeable. Its removal proved extremely difficult.

Figure 52 A thick film of salt that crystallised beneath a hard render, which was in turn finished with a high-build (thick) paint coating. For evaporation (and hence salt crystallisation) to occur the render must first have become partially detached from the brickwork. Thermal cycling would then drive air movement, allowing evaporation. The salt was chiselled off and the brickwork poulticed before re-rendering.

Repairs to interior plasterwork are commonly required when dealing with a damp problem, whether its origin is rising, falling or penetrating. In each case it will be important to cut off or minimise the source of moisture and to remove any salts prior to replastering. This section expands on some of the issues with interior plasters and rising damp.

Prior to undertaking the insertion of a damp-proof course (by whatever method), plaster is removed from interior walls up to at least 300 mm above the upper limit of elevated salt and damp readings, as measured with a moisture meter — used with informed caution as explained in Section 11.2.

This is when some unhappy discoveries may be made. The building may have been previously treated for salt damp and the discoveries may include corroded remnants of copper wire electrodes from a passive electro-osmotic treatment, replacement masonry from a partial undersetting of the walls, and hard impervious renders trapping moisture and salt within the walls (Figure 51). The hard render may have delaminated in places, leaving a film of salt crystallising in the space between render and wall (Figure 52). The render, which may have been formulated to be waterproof and may be an extremely hard mix of almost neat cement, will need to be removed to allow desalination.

Desalination can begin straight away and need not wait for DPC insertion. Indeed, beginning the desalination before treatments such as chemical impregnation has some advantages, including protecting the wall above from a sudden flushing of salt that may be displaced by the injection of dampcoursing fluid (see Section 16.3: *Chemical impregnation*).

Some contractors claim that the old plaster acts sacrificially, making poulticing unnecessary. While there is some truth in this, the overall effect will be slight, particularly as paint coatings will slow the drying while multiple coats may stop it altogether. Where there is a lot of salt, it is better to remove the old plaster and to poultice the underlying masonry.

After thorough desalination and insertion of a new DPC, the walls can be replastered. So that the new plaster will be compatible with the wall, its materials should be similar to those of the original. The replacement plasters for old walls of flexible masonry should also be soft and flexible and made of lime, whereas a stronger cement-lime plaster may be appropriate for newer and stiffer walls on rigid footings. The amount of gypsum (plaster of Paris) in the final (set) coat will be determined in the same way: less for old flexible walls and more for younger stiffer walls.

Figure 53 Damaged plaster on a damp wall; the dampness is indicated by green algae and white salts crystallising on the stonework and fill below. The recent plaster is decaying because it contains gypsum.

Gypsum plasters should not be used where there is any risk of continuing dampness. This is because gypsum, which is calcium sulphate ($CaSO_4 \cdot 2H_2O$) is a slightly soluble salt and any moisture will trigger salt attack within the new plaster (Figure 53). Use only lime or lime-cement plasters where walls may be subject to continuing dampness. Portland cements contain gypsum and other salts which may add to a damp problem. Specify low-alkali cements to keep salts to a minimum.

After replastering comes thorough drying, not only of the construction water introduced with the plaster, but of any residual dampness from deep in the wall. Depending on the climate this may take 3–6 months, or even up to 12 months for wet thick walls in cooler damp climates. Without thorough drying before repainting, bubbling paint films are almost guaranteed.

Whereas in the past prolonged drying was accepted as a necessary part of constructing masonry buildings with solid plasters, such understanding is less evident today. The demands to complete the job and to quickly tidy up someone's living or working area has meant that some contractors offer alternative approaches to the best practice method described above. These alternatives generally include the addition of waterproofing additives to the first plaster coat (the render coat) with the aim of preventing moisture damage to new paint coatings. To make these work, the render coat is made with a rich cement-sand mix which will be too strong for old walls.

Depending on the nature and amount of the additive, the render coat can be made moderately or strongly hydrophobic (waterproof). Strongly hydrophobic treatments will prevent evaporation from any continuing rising damp and may be being used as a belts-and-braces approach in case DPC insertion has not been adequate. However, in twenty or thirty years the damp will have risen above the hard render and will once again break out (Figure 20), requiring a new round of treatment. Less strongly hydrophobic additives (such as some salt retarders) will allow the wall to breathe and dry, but will not prevent active rising damp from damaging the plaster. At least these are more honest, as any failure of the DPC will become apparent relatively quickly. However, there remains the potential incompatibility of the hard and brittle cement render on what may be soft and flexible walls.

While the desire to complete repairs quickly may lead some to accept the use of hard render coats that contain additives to control or prevent drying, these treatments are not best practice and should not be used in buildings of considerable heritage value. **Good practice requires the removal of as much salt as possible and thorough drying before repainting.**

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22 Repainting

The choice of paint type is important in situations where walls are damp, particularly when salts are present. As walls get older and accumulate salts, the need for good breathing increases. Unfortunately, many modern paints are less vapour-permeable than traditional coatings; they don't allow the wall to breathe as effectively as the older ones.

Acrylic (water-based) paints are more vapour-permeable than alkyd (oil-based) paints; the latter should not be used where walls remain damp or are still drying out after DPC insertion. Even the acrylics can be too impermeable for old walls (Figure 54). In these circumstances alternative coatings such as cement-based paints and traditional limewashes should be considered. Limewashes are more vapour-permeable than cement-based paints.

Figure 54 Failure of an acrylic paint coating due to salt damp. The bottom part of the wall is rendered in cement, which has contributed to the damp rising further due to its relative (but not total) impermeability. Decay of the brickwork is focussed where the paint film fails because that's where salt crystallises as moisture evaporates. The paint and the render should be removed and replaced with a more vapour-permeable coating such as limewash.

Buildings of heritage value that were traditionally painted in limewash should be repainted in limewash, not only because it is the authentic finish, but because it has the greatest breathing capacity of all coatings.
Be aware that some modern 'limewashes' (and cement-based paints) contain acrylic or other resins and their breathing capacity may be no better than normal paints. Look for limewashes that have a minimum of organic resin binders, or alternatively, make your own from lime putty, water and pigments.

23 Cellars and basements

Cellars and basements present particular problems because of the risk of groundwater penetrating horizontally through the walls, causing salt attack on the inside faces, and creating damp internal environments. Flooding of cellars is common where groundwater tables are shallow, or where the subsoils are heavy clays which form temporary watertables, diverting some of the water through the cellar. The internal lining of cellar walls with impervious membranes is often proposed. While it may limit water inflow, it will simply drive the damp higher up the walls and is not recommended.

There are several approaches to cellars with salt damp. One is to keep the cellar tightly closed, thus reducing evaporation and the rate of decay. Under such conditions, salts may crystallise relatively benignly on the face of the walls as efflorescence, rather than just beneath the wall surface where they do damage. This option will only be viable if the damp does not rise further in the walls. Often a better alternative is to add some (but not too much) ventilation, and seek to manage salt attack decay with sacrificial plasters and limewash coatings. Both these approaches may limit the future uses of cellars: the latter may lead to unsightly crumbling plaster, and the former to very high humidity levels, which will preclude even normal storage functions.

Making cellars and basements habitable may require more substantial treatments including excavation along the outside of the cellar or basement walls and the installation of a drainage system with vertical moisture barriers against the wall surfaces (tanking). This is expensive and often difficult to achieve in an existing building (geotechnical engineering advice may be required — see Section 12.2: *Site drainage*). The installation of a DPC in the base of the walls might then be considered, together with removal of salts from the wall surfaces. Floors may also need to be made impervious, and in practice this is expensive, with few examples of success.

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24 Old treatments

Over the years there has been a range of different treatments for rising damp, many of which have proved to be unsatisfactory. Some of the more common include hard cement renders, damp-proof mortar additives, Knapen tubes, and passive electro-osmosis. These methods should no longer be considered.

24.1 Hard cement renders

A rich cement render along the base of walls can be seen disfiguring many buildings (Front cover). Because these renders are relatively impermeable, they prevent evaporation of rising damp. At best this is a short term solution, for (as explained in Section 13: *Sacrificial treatments*) the damp will eventually rise and cause decay above the render. Alternatively, the damp may cause damage by evaporating through wall cavities or the inside faces of solid walls.

The remedial treatment of hard-rendered walls should begin with an assessment of the thickness of the render and of the extent of original wall material lost prior to the application of the render. By carefully hammering across the face of the render, it may be possible to break it into small pieces, which can then be removed with minimal damage to the original masonry. Because of the quite different mechanical properties of the render and the wall, many renders will be found to be partially detached, often with salt crystallising at the interface. Remove any surface salt by brushing, vacuuming or light chiselling and desalinate the wall as explained in Section 14.

Decisions then need to be made about the desirability of a damp-proof course and the finished appearance of the wall: whether it can be returned to its original face brickwork or stonework, or whether the extent of decay and costs of repair mean that it needs to be re-rendered. If re-rendering, seek to make the render compatible with the underlying masonry. If the wall is soft and flexible, make the render the same. If there's any likelihood of salt remaining in the wall, the new render should act sacrificially. Incorporate porous particulates in the render mix to provide storage space for the salt and prolong the render's life (see Section 13.1: *Sacrificial mixes*). Finish with limewash to allow it to breathe.

24.2 Atmospheric syphons

Atmospheric syphons, also known as Knapen tubes, are lightly fired ceramic tubes that were mortared into holes drilled in walls with plastic or metal covers over the exposed ends. They were intended as drying aids, based on the principle of drawing moisture into the small pores of the ceramic and then encouraging it to evaporate into the hollow tube and then to pass into the atmosphere. However, tests have shown that an empty hole is just as effective in drying the surrounding wall. Further, when the natural rate of evaporation from the wall surface is greater than is possible from the tube or empty hole (and this is the norm) they will not add significantly to the drying of a wall. In high salt conditions the ceramic tube is rapidly destroyed by salt attack.

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25 The future

Although most Australian buildings are less than 200 years old, we want those of heritage value to last many hundreds more. Many will now be at a critical stage in their salt damp history, and many more will reach this stage in the coming decades, particularly those with ineffective damp-proofing. The long term management of these buildings will require regular maintenance, attention to good housekeeping, and periodic inspection of wall cavities and underfloor spaces to check the condition of normally unseen parts of walls.

Accurate diagnosis is critically important; there is no substitute for a thorough understanding of a building's behaviour and its response to changes over time. Minor changes can have a significant impact, both positive and negative. Make small changes first, then assess their effectiveness before deciding on more expensive treatments like the insertion of damp-proof courses.

There is a need for the damp-proofing industry to also become salt-removalists, and to recognise that removing salt is as important as damp-proofing. There is also the need for the damp-proofing and pest control industries to come together and overlap to the extent that pest inspectors checking for termites should be able to comment in an informed way on the condition of walls beneath floors. Equally, damp-proofing contractors should undertake works in such a way as to minimise timber decay and, where needed, should install suitable protection for floor timbers.

Finally, those who commission, specify, fund and live with salt damp remedial works should do so knowing that the business is as much about salt as it is about damp, and in full knowledge of the ongoing need for maintenance and of the limitations and risks associated with partial treatments that deal only with the more obvious symptoms.

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The slate doorstep

In recent years several examples have come to light of replacement slate doorsteps failing after only a few years in service. The following case study provides a valuable insight into an important aspect of salt damp.

A brick house built in about 1900 had a slate front doorstep. Mild damp affects parts of the house particularly near the front door, causing the doorstep to delaminate and become powdery on the surface due to salt attack. The badly worn step was replaced in the mid-1980s with a new piece of slate from the same quarry. Within five years the new step began to decay in the same manner (Figure 55, below). What happened? Why did the first step last eighty-odd years and yet the second need replacing after ten? Perhaps the slate is not what it used to be?

The answer to the last question is a definite no: the slate is the same sound, relatively durable material it always was. So why did the second one fail in such a short time?

The explanation is that it took eighty years for rising damp to draw salts from the soils up into the walls to a concentration sufficient for it to cause decay in the first step (see Figure 17 in Section 9.4). The second step was built into this already salt-laden environment and so it began to decay shortly afterwards.

The dense layered nature of slate contributes to its demise — its very fine pore structure has a high suction along the layers, while being relatively impermeable across the layers. Thus the slate will draw any available moisture in from its edges — edges which are butted against salty brickwork.

The third step, which is now doing fine after ten years, had its edges sealed with slate sealer prior to installation (several coats of siloxane dampcourse fluid would be an alternative). The new step is bedded on a plastic DPC and on weak mortar that will decay sacrificially in preference to the adjacent brickwork.

Box 9, Figure 55

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Glossary

Aggregate Hard and generally inert material used as a filler in mortars and concrete: coarse aggregate = gravel; fine aggregate = sand.

Bluestone Hard, dense, dark coloured stone, occasionally bluish. In Victoria, volcanic basalt; in New South Wales, includes granite-like metavolcanics; and in South Australia, sedimentary rocks such as siltstones and shales.

Capillarity Capillary action: suction of fine tubes, related to surface tension, drawing water sideways or against gravity in fine-pored materials.

Captive-head washing Cleaning system with a water jet within an enclosed hood which is equipped with a powerful vacuum to capture the dirty wash water.

Case hardening Hardening of the outer skin of sandstones, limestones and some other types due to solution and re-precipitation of some of the natural cementing material within the stone. Retaining its case hardening can be critical to a stone's durability.

Contour scaling The loss of a thin scale (commonly the case-hardening) from the surface of a stone, often (but not always) caused by salt attack.

Coping Capping of the top of a wall in stone, brick or concrete.

Cornice On exteriors the cornice is the horizontal or near horizontal projection from the base of the parapet at the top of the building; designed to shed water and protect the walls below.

Damp-proof course (DPC) A layer of impervious material (e.g. polyethylene) built into walls to prevent the upward migration of water. Also called a dampcourse. Remedial damp-proofing may include chemical DPCs.

Damp-proof membrane (DPM) As for a DPC but generally used to describe the thinner sheet material used beneath concrete slab footings.

Deliquescence Deliquescent materials are those which absorb water vapour from surrounding air and dissolve into it, forming a solution.

Desalination The removal of salt, in this case from masonry materials.

Dew point The temperature at which water vapour in air condenses as liquid droplets (condensation).

Diatomaceous earth A natural deposit of fossil 'skeletons' of tiny organisms (diatoms).

Efflorescence Crystallisation of white powdery salts on the surface of masonry.

Electro-osmosis Movement of liquid under an applied electrical field.

Evaporative front Line within masonry at which evaporation from liquid to water vapour takes place. The front may move with changes in weather.

Evaporative zone Zone of a wall through which evaporation occurs, often 0.5–1.2 m above ground level when DPC is absent or ineffective.

Falling damp Dampness in buildings resulting from water entering at upper levels and percolating downwards; as distinct from rising damp.

Flashing A strip of impervious material such as lead or other metal fitted into walls to provide a barrier to the movement of moisture.

Footing The widened base of walls that spreads the load to the ground beneath; traditionally of stone or brick, now of reinforced concrete.

Header A brick laid with its long dimension across the plane of a wall so that its end is visible in the wall face (see stretcher).

Hydrophobic Water repellent material.

Hygroscopic Materials that attract moisture from air. Some are also deliquescent.

Impervious A material that does not permit water or other fluids to pass through; one that is impermeable (see permeability).

Masonry Bricks, Concrete bricks or blocks, stone and terracotta laid in mortar to form walls or other structures.

No-fines concrete Concrete made without fine aggregate (sand) so as to be porous and permeable.

Osmotic pressure Pressure required to stop the flow of a dilute salt solution towards a more concentrated salt solution across a semi-permeable membrane.

Parapet Low wall projecting above the line of a roof.

Penetrating damp Horizontal penetration of dampness into walls.

Permeability The property of a porous material that allows fluids such as water to pass through it. Impermeable materials don't (see impervious).

Plaster Lining of internal walls or ceilings (see render).

Porosity The void (or pore) space in a material, expressed as a percentage.

Rainwater head A box-like fitting at the top of a downpipe that collects and discharges rainwater from roof gutters.

Render Covering of external walls in mortar-like materials. The term is also for the first coat of plasters.

Repointing The replacement of the outer part of the jointing material in brick and stonework. Usually includes the weatherproof surface "pointing" and some of the softer mortar behind it.

Rising damp Upward capillary migration of water in masonry.

Salinity Soluble salts in soils, natural waters and the environment.

Salt attack Decay of masonry materials due to the crystallisation of soluble salts within the pores of the material; see also salt weathering.

Salt damp A term originating in South Australia that neatly combines the two discrete phenomena of salt attack and rising damp.

Salt weathering The same process as salt attack, but applied more broadly, e.g. in geomorphology, to the weathering of landforms.

Saturated solution A solution containing the normal maximum amount of salt.

Solute suction The osmotic pressure of a salt solution — drawing less saline water towards the more saline, so as to dilute it.

Stretcher A brick laid with its long dimension horizontally along a wall.

Subflorescence Crystallisation of salts within the pores of masonry. Sometimes referred to as crypto-efflorescence, meaning hidden.

Suction The negative force exerted by the capillarity of porous materials. It draws water into walls and aids in adhesion of plaster and mortar.

Supersaturation A salt solution which is over saturated in salt which has not yet crystallised out.

Termites Commonly called white ants, termites belong to a different order of insects; their food consists of cellulose in trees, grass and timber.

Urban Salinity Recently coined term encompassing the combined impact of water and salt on the urban environment, including buildings, roads and other infrastructure. Includes salt attack and salt damp.

Undersetting Salt damp treatment in which sections of the base of a wall are progressively rebuilt in new materials, incorporating a DPC.

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27 Further reading

27.1 General references

Ashurst, J. & N. 1988. *Practical building conservation*. English Heritage technical handbooks, 5 volumes, Gower Technical Press, Aldershot, Hants, UK. *Volume 2: Brick, terracotta and earth*. ISBN 0-291-39746-8.

Burkinshaw, R. & Parrett, M. 2003. *Diagnosing damp*. RICS Books, Coventry. ISBN 1-84219-097-0.

CCAA. 2005. *Guide to residential slabs and footings in saline environments*. Cement Concrete & Aggregates Australia, Sydney. ISBN 1-877023-14-0.

Charola, A.E. 2000. 'Salts in the deterioration of porous materials: an overview'. *Journal of the American Institute for Conservation*, Volume 39, No 3. Viewed 27 May 2008 (http://aic.stanford.edu/jaic/articles/jaic39-03-002.html)

CSIRO. 2003. *Lectros Electro Osmotic Dampcourse System, Technical Assessment 308*. (renewed 2006) CSIRO Appraisals, Highett, VIC.

Doehne, E. 2002. '*S*alt weathering: a selective review'. In: Siegesmund, S., Weiss, T. & Vollbrecht, A. (eds). *Natural stone, weathering phenomena, conservation strategies and case studies*. Geological Society, London, Special Publications, 205, pp 51–64.

Goudie, A. & Viles, H. 1997. *Salt weathering hazards*. Wiley, Chichester, NY. ISBN 0-471-95842-5.

Heiman, J.L. & Riley, K.W. 2000. 'Salt attack and treatment in sandstone and brick structures'. In: McNally, G.H. & Franklin, B.J. (eds). *Sandstone city: Sydney's dimension stone and other sandstone geomaterials.* Monograph 5, EEHSG, Geological Society of Australia, Conference Publications, Springwood, NSW. pp 125-137. ISBN 1-876315-22-9.

López-Arce, P., Doehne, E., Greenshields, J., Benavente, D. & Young, D. 2008. 'Treatment of rising damp and salt decay: the historic masonry buildings of Adelaide, South Australia'. *Materials and Structures*, RILEM (DOI: 10.1617/s11527-008-9427-1).

Massari, G. & I. 1993. *Damp buildings, old and new*. ICCROM, Rome. ISBN 92-9077-111-9.

NSW Department of Natural Resources. Local Government Salinity Initiative Booklets, including: 5 *Introduction to urban salinity*. 6 *Building in a saline environment*. 12 *Repairing and maintaining salinity affected houses.*

Oliver, A.C. 1997. *Dampness in buildings*. 2nd edn, revised by J. Douglas and J.S. Stirling, Blackwell Science, Oxford. ISBN 0-632-04085-8.

Oxley, T.A. & Gobert, E.G. 1994. *Dampness in buildings: diagnosis, treatment, instruments*. 2nd edn, Butterworth-Heinemann, Oxford. ISBN 0-7506-2059-5.

Richardson, B. 2001. *Defects and deterioration in buildings: a practical guide to the science of material failure*. 2nd edn, Taylor & Francis, London. ISBN 0-419-25210-X.

Rose, W. B. 2005. *Water in buildings: an architect's guide to moisture and mold*. Wiley, Hoboken, NJ. ISBN 0-471-46850-9.

Salt Damp Research Committee. Adelaide. Reports (1976, 1978, 1981); Information Papers (6); Booklets: *The scourge of salt damp in buildings*. 1977; *How to avoid salt damp*. 1978; *Living with salt damp*. 1980.

The Bible. Leviticus. Chapter 14, verses 33–45, (King James version).

Torraca, G. 1988. *Porous building materials: materials science for architectural conservation*. 3rd edn, reprinted 2005, ICCROM, Rome. ISBN 92-9077-198-4.

Trotman, P., Sanders, C. & Harrison, H. 2004. *Understanding dampness: effects, causes, diagnosis and remedies*. Building Research Establishment, Watford. ISBN 1-86081-686-X.

Young, David. 1995. *Rising damp and salt attack*. South Australia, Department of Environment and Natural Resources, and the City of Adelaide, Heritage Conservation: 3.8. ISSN 1035-5138.

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27.2 Standards and codes of practice

ABCB. 2008. *Building Code of Australia 2008*. Australian Building Codes Board, Canberra. ISBN 1-921453-06-9 (Volume 1), ISBN 1-921453-07-6 (Volume 2).

British Standards Institution. 2005. *Code of practice for diagnosis of rising damp in walls of buildings and installation of chemical damp-proof courses*. BS 6576:2005. ISBN 0-580-46867-4.

Standards Australia. 2001. *Methods of sampling and testing mortar for masonry constructions*. Australian Standard AS 2701—2001, Standards Australia, Homebush, NSW. ISBN 0-7337-3638-6.

Standards Australia. 1995. *Damp-proof courses and flashings*. Australian Standard AS/NZS 2904—1995, (& Amendment 1, 1998) Standards Australia, Homebush, NSW. ISBN 0-7337-0054-3 & ISBN 0-7337-1726-8.

Standards Australia. 2007. *Inspection of buildings*, Part 0: *General requirements*. Australian Standard AS4349.0—2007, Standards Australia, Sydney, NSW. ISBN 0-7337-8503-4.

27.3 Internet links

Adelaide City Council *www.adelaidecitycouncil.com/heritage*

Heritage Branch, NSW Department of Planning
www.heritage.nsw.gov.au

Heritage Victoria, Department of Planning and Community Development
www.heritage.vic.gov.au

Heritage Branch, South Australian Department for Environment and Heritage *www.environment.sa.gov.au/heritage*

28 Acknowledgements

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