RISING DAMP AND SALT ATTACK IN OLD MASONRY BUILDINGS

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ABSTRACT Rising damp problems are often encountered in old masonry buildings. Moisture in contact with the bases of porous masonry walls moves upward by capillary attraction unless there is an effective barrier to prevent this movement. The moisture invariably contains soluble salts that can cause deterioration of the masonry and surface finishes. Salt attack can result also from other causes such as marine aerosols or by rain penetration where the rainwater is contaminated by urban pollution. The paper deals with rising damp and salt attack and with their treatment.

1. INTRODUCTION

The rehabilitation or recycling of old masonry buildings frequently involves repairs where damage has been caused by various forms of moisture penetration. Rising damp problems are not uncommon where either there are no damp-proof courses or the damp-proof courses have broken down or have been bridged. The moisture that migrates up the walls invariably contains dissolved salts which are deposited near or at wall surfaces where they can have a disruptive effect on the masonry and wall finishes. Damaging levels of salt contamination can also result from other sources such as urban pollution and from deposition of marine aerosols in coastal areas.

2. SYMPTOMS OF RISING DAMP

A typical sign of rising damp on internal walls is a roughly horizontal tide mark above which there is little or no damage but below which the paint or plaster has been damaged or the wallpaper is stained or has lifted. On external walls it may be indicated by fretting masonry or by peeling paint close to ground level. The dissolved salts associated with this moisture movement (commonly chlorides, sulphates and carbonates) are deposited near or at the wall surfaces where evaporation takes place. Efflorescence may appear on surface coatings and the masonry may deteriorate as a result of expansive disruption associated with salt hydration and crystallisation.

Sometimes the level of this tide mark appears fairly stable which might suggest that rising damp is a static process, but this is not the case. The amount of dampness in a wall will be influenced by the interaction between the rate of evaporation and the rate of ingress of moisture into the wall. Frequent changes in these two factors and in temperature and humidity will alter the dynamic equilibrium associated with moisture movements in the wall.

Mould growths might appear on persistently damp surfaces. On external surfaces, efflorescence and mould growth might also be accompanied by fretting of the stone or brick and crumbling of the mortar. There can be a unpleasant smell in the affected rooms and prolonged dampness can lead to decay of the skirting boards. The damage is commonly restricted to a zone which does not extend more than 1 to 1.5 m above the floor, although in very damp situations the damage can occur at higher levels, particularly where there is poor ventilation.

The height of the capillary rise of moisture in a wall will be influenced by the size of the capillary spaces in the masonry, the smaller the capillaries

the higher the capillary rise. It will also be influenced by the rate of evaporation from the wall. An increase or decrease in the rate of evaporation will be accompanied by a fall or rise in the height of the zone of dampness. In addition, the height of the water table will affect the height of the capillary rise. Hence, the size of the damp zone in a wall can fluctuate with seasonal changes in climate. During a dry period the soil around the base of the wall will draw moisture out of the masonry. A wet season accompanied by a rise in the water table can result in an increase in the height of the capillary rise of moisture.

3. DIAGNOSIS

Faulty diagnosis of a dampness problem can result in ineffective treatment. Damage caused by rising damp is sometimes confused with that caused by falling damp where the moisture comes from leaking roofs or downpipes, through defective flashings or from blocked gutters. Dampness problems can also be caused by the lateral penetration of rainwater through porous bricks and porous or defective mortar joints in solid masonry walls. Lateral rain penetration can also occur across brick cavity walls when the ties are coated with mortar or the cavity is blocked with mortar droppings or building debris. It can also be caused by leaking internal pipes. At other times the dampness can be primarily a condensation problem resulting from a build-up of humidity and a lack of ventilation. Sometimes it is the result of a combination of causes.

A treatment suitable for one type of dampness problem might be inappropriate for another. A thorough examination of a building should be carried out by an experienced person before remedial measures are undertaken.

4. DAMP-PROOF COURSE FAILURES

Rising damp problems can be caused by the bridging of the damp-proof course which allows water to rise up the wall above the level of the membrane. This can sometimes be rectified without much difficulty or expense.

As shown in Fig. 1 some common sources of bridging action are

(a) the heaping of soil or debris against the wall.

(b) the location of a concrete path or floor slab directly against the wall.

(c) the building up of mortar droppings or other debris inside the cavity.

(d) failure to extend the damp-proof course a sufficient distance across the wall so that moisture can travel up the wall through the render or mortar pointing.

(e) perforation of the damp-proof course by building operations and subsequent bridging.

5. TREATMENT OF RISING DAMP

Sub-surface seepage and the presence of a high water table under a building where there are no effective moisture barriers in the walls can cause a dampness problem which may sometimes be eliminated by the installation of sub-surface drainage.

Excessive watering of garden beds and lawns close to the building or the presence of leaking services can be contributing factors. Downpipes that discharge stormwater into the ground close to masonry walls can also exacerbate a rising damp problem. In some cases it may be appropriate to replace garden areas with aprons or paths that slope away from the building to remove the need to water and to divert surface run-off away from the walls. The paving materials should be sufficiently pervious to ensure that subsurface moisture underneath can evaporate rather than migrate into the walls.Permeable types of concrete or brick paving blocks are suitable for this purpose.

Measures that lead to an increase in the rate of drying out of walls are helpful in overcoming dampness problems. These include increased ventilation below and above ground floor level and the removal of almost impervious surface coatings such as hard plaster and oil-based paints and their replacement by surface treatments that allow the wall to breathe.

The rate of evaporation will be influenced by the relative humidity of the surrounding air and the amount of air movement past the damp wall. Drying can often be increased appreciably by artificial heating and improved ventilation.

At the same time it should be remembered that treating the dampness by these methods will not always solve the problem. An increase in the rate of drying may also result in an increase in the amount of salts deposited at the wall surface, and deterioration may increase rather than diminish, at least for some time after the drying out process has been accelerated.

Where hygroscopic salts have accumulated in old render or plaster, the surface finishes should be removed after a treatment to prevent rising damp has been carried out. It is advisable not to replace the surface finish until some months later in order to assist the drying out of the wall. Very thick masonry walls can take years to dry out completely.

It may be possible to remove part of the salts, which are brought to the surface of the masonry by the increased drying, by brushing. However, where walls are heavily contaminated it may not be possible to remove a sufficient amount of salt by this method and poulticing or flushing techniques described later may be necessary to reduce the salt content to a satisfactory level.

5.1 Insertion of a new Damp-proof course

The insertion of a new damp proof course is an effective method of overcoming a rising damp problem provided the installation is carried out satisfactorily, but high costs or practical difficulties may rule it out, for example where the wall is excessively thick or it is of rubble construction. It can be accomplished by removing a few bricks at a time from a course of brickwork near the base of the wall, inserting a section of the damp proof course along the horizontal bed joint, replacing the bricks and mortar, and repeating the process until a continuous membrane has been placed in the brickwork affected by the dampness. A less tedious method which does not require removal of bricks is to cut a short narrow slot along a bed joint with a power-driven reciprocating saw or abrasive disc. Special chain saws have also been used for this purpose. Walls over 600 mm thick have been slotted successfully with a high pressure water jet. Some form of wedging might be required during the insertion of the damp-proof course to prevent settlement damage.

If the walls are heavily charged with salts, insertion of a new damp-proof course may result in an increase instead of a decrease in the rate of deterioration unless the salt content is reduced to non-damaging levels.

5.2 Chemical Injection

The aim of a chemical injection treatment is to form a barrier to moisture movement either by blocking the continuous voids in the masonry or by forming a water-repellent film on the walls of pores and capillaries. This alters the surface tension forces at the solid-liquid interfaces thereby impeding the upward movement of moisture. Mixtures of rubber latex and siliconates have been used as pore fillers. Solvent-based silicones, aluminium stearates and water-based siliconates have been used to form repellent films. As water repellents line but do not block pores and capillaries, they allow the passage of water vapour through the masonry and are therefore unsuitable for the damp-proofing of basements and walls subjected to hydrostatic pressure.

The chemical solutions are injected under pressure or percolate by gravity into the masonry through holes drilled at intervals near the base of the wall. The success of a treatment will depend largely on the effectiveness of the penetration. The formation of a continuous barrier will be influenced partly by the choice of a suitable spacing between the holes. Ideally the saturated zone of masonry formed around each hole by the injected solution should overlap those formed around the adjacent holes. In practice it is not always possible to meet this objective and this is one reason why chemical injection treatments are not always successful.

Sometimes effective penetration by pressure injection cannot be achieved because an excessive amount of fluid is lost in voids in the masonry. The presence of weak mortar unable to withstand the pressure of the injection solution can lead to excessive losses and incomplete penetration.

As these treatments have been in use in Australia for less than 10 years it is not yet possible to assess their likely long-term effectiveness. Chemical injection systems have been used successfully in the U.K. for a much longer period. With some treatments it is possible to carry out a supplementary impregnation at a later stage to extend the life of the system.

5.3 Damp-proof Mortars

Damp-proof mortars to which admixtures such as stearates or bituminous compounds are added to reduce the permeability of the mix have been used for many years in parts of Australia, particularly in Victoria and South Australia but their use for damp-proof courses is not permitted in NSW. They are usually cheaper than sheet damp-proof membranes and in many instances they have prevented rising damp. There have also been reports of failures and it is generally recognised that they are not as reliable as sheet membranes. Where failures occurred they were often attributed to faulty workmanship or unsuitable mortar mixes. Mix proportions were specified incorrectly or the mortar was not batched according to the specification. The BRDI(1) recommends that when proprietary admixtures are used to make damp-proof courses the mortar should contain not less than 1 part of cement to 4 parts of washed sand (by volume). Sometimes unsuitable sands with high clay contents are used and excessive shrinkage and cracking of the mortar results. Damaging foundation movements will result also in cracking of the joints and dampness problems. The use of admixtures will not prevent dampness in these situations.

5.4 Surface Treatments

5.4.1 Coatings. The application of impervious surface coatings on walls where there is rising damp might not provide a permanent and effective solution to the problem. Often it will result in an increase in the height of the capillary rise of the moisture or it can result in the dampness appearing on parts of the walls which were previously unaffected, Fig. 2. There is also the possibility of failure because of a loss of adhesion of the coating caused by disruptive forces associated with salt deposition close to the interface between the coating and the masonry.

5.4.2 Linings. In another treatment designed to conceal rather than to stop rising damp, a lining material such as hardboard or plasterboard is nailed to timber battens fastened to the wall, thereby leaving an air gap between the lining and the damp wall. It is necessary to impregnate the battens and plugs with a preservative to protect them against decay and to use rust-resistant fastenings. A treatment of this type would have to be carried out on both sides of an internal wall otherwise it will only aggravate the problem on the untreated face. It could also eventually result in dampness appearing beyond the area of concealment.

5.5 Other Methods of Treatment

EBS has investigated other methods of treating rising damp including passive electro-osmosis, expansive cementitious grouts and Knapen tubes. None of the systems examined was found to provide a reliable answer to the problem.

The promoters of the electro-osmotic system claimed that an electrical potential was created by the upward moisture movement in a damp wall and that by inserting a continuous copper strip in holes at the base of the wall and earthing it, a short circuit resulted, which eliminated the difference in potential and thereby stopped the upward moisture movement. Tests carried out by EBS and the CSIRO failed to substantiate these claims (2). Although some successes were reported in field applications there were also a number of failures and the method is no longer used in this country.

In another proprietary system, a cementitious grout consisting of a mixture of portland cement, sand and unspecified chemicals was introduced into holes in the damp wall and it was claimed that crystals formed in the pores of the masonry as a result of a reaction between the grout and moisture in the wall, blocking the voids and thereby creating a barrier to rising damp. Tests on two treatments of this type failed to substantiate this claim.

In a third method, Knapen tubes are inserted in inclined, blind holes drilled at intervals close to the base of the wall. They are made from lightly-fired clay or from perforated metal or plastics and it is claimed that air currents set up inside them increase the rate at which moisture evaporates from the wall. EBS tests on ceramic tubes inserted in a brick wall showed that they did not overcome the dampness problem.

6. SALT ATTACK

Salt movements are invariably associated with rising damp and depending on their nature and concentration and the properties of the masonry and surface finishes, they may or may not cause damage to the building. In some localities, particularly in parts of South Australia, damage to masonry caused by salt damp attack can be a serious problem. Typical damage caused by salt damp attack are disruption of render or plaster and fretting of exposed

masonry including crumbling of mortar joints.

6.1 Other Sources of Salt Attack

Harmful salts encountered in masonry construction can also come from sources other than rising damp. They can come from the atmosphere via air-borne particulates and rainwater, from mortar and from unsuitable cleaning agents. They might have been in the stone or bricks before they were laid.

In the larger cities increasing atmospheric pollution caused mainly by fuel combustion has resulted in the formation of quantities of sulphur dioxide which combines with moisture in the atmosphere to form sulphuric acid. The acid subsequently reacts with calcite in limestone and calcareous sandstone and with the lime in mortar to produce gypsum. The formation of gypsum is associated with an appreciable increase in volume which can disrupt brick or stone masonry.

Atmospheric aerosols of marine origin are another significant source of sulphate and chloride contamination of masonry in coastal areas. A study of the composition of rainwater in the Sydney basin (3) has shown that east and south-east winds bring large amounts of sea salts as aerosols across the coast and they are deposited on buildings.

6.2 Mechanism of Salt Attack

The mechanism of salt attack is not fully understood but it usually involves damaging expansive forces associated with crystal growth or with volume changes that occur when certain soluble salts go through cycles of hydration and dehydration induced by changes in temperature and humidity. For example, sodium sulphate can occur in an anhydrous form, Na_2SO_4, or as the heptahydrate $Na_2SO_4 . 7H_2O$ or as the decahydrate, $Na_2SO_4 . 10H_2O$ depending on temperature and humidity, Figs. 3 and 4. Other salts such as calcium or magnesium chlorides or nitrates are hygroscopic and can take up moisture directly from the atmosphere and retain it in the masonry. Then later, when a drying phase occurs, crystal growth can exert a damaging pressure against the pore walls.

The amount of salt disruption will be influenced not only by the permeability of the masonry but also by the pore size distribution. Often the resistance of masonry to decay decreases as the amount of fine pores increases.

6.3 Clay Bricks

The severity of salt attack depends on the vulnerability of the masonry. Unfortunately a number of early 19th century buildings in Australia were constructed with sandstock bricks which were fired at temperatures well below 1000°C and are characterised by limited vitrification and the presence of unburnt clays. They usually have a porous structure with extensive cracks and voids and have a low mechanical strength and a high permeability. Consequently they are likely to fret badly when exposed to salt attack.

The replacement of badly decayed sandstocks with undamaged sandstocks might be impracticable or inappropriate and it may be necessary to substitute modern bricks with a similar appearance to the original sandstocks.

Salt attack problems are not confined to old buildings of sandstock bricks. They can occur also in modern construction where light-coloured, underfired

clay bricks are not sufficiently durable for the severity of the exposure. Such situations can occur when they are placed below damp-proof course level on highly saline soils or they are exposed to salt spray in coastal areas, Fig. 5.

If replacement becomes necessary or new work is being undertaken in salty environments, a well-fired brick (above 1100°C) with a low permeability and a good resistance to salt attack should be used. The water absorption and sulphate tests given in AS 1226 can be helpful in the selection of a durable brick. For example an extruded brick that has a cold water absorption less than 6 per cent and survives 40 cycles of immersion in the sodium sulphate solution is likely to have a good resistance to salt attack.

6.4 Mortar

Mortar requirements in the preservation of historic masonry buildings are often different from those encountered in modern, load-bearing brickwork. In old masonry construction, stresses resulting from vertical and lateral loading are usually low and load considerations do not play a major part in the selection of a suitable mortar. The main criteria are likely to be durability and weathertightness. In this context, strong cement mortars are frequently inappropriate because of their tendency to crack and separate from the masonry unit because of differential movement so that rain penetration takes place between the masonry units and the mortar.

In urban or marine environments where aggressive substances and salts attack the masonry it is essential that repair work should include measures to prevent their penetration. Repointing of defective joints is therefore often required in the restoration of old buildings.

Although in some situations portland cement can contribute to the durability of masonry mortar it also has disadvantages. Cement-rich mortars have a tendency to develop shrinkage cracks which permit moisture to enter the fabric and at the same time their low permeability makes it difficult for the moisture to escape. If the masonry is already contaminated with soluble salts, low permeability joints encourage salt deposition in the adjoining masonry where fretting can occur, Fig. 6. Lime mortar or weak composition mortars (1:2:9 or 1:3:12) are preferable where their higher permeability will encourage migration of the salts into the joints. The joints will deteriorate but it is easier to repair decayed joints than decayed masonry. Lime-rich mortars are also more flexible than strong cement mixes and are better able to accommodate cyclic stresses that occur in external masonry as a result of frequent changes in the temperature and moisture content of the masonry.

Field surveys and measurements (4) have shown that failure of masonry joints is most likely to occur near roof level, in parapets, cornices and other horizontal or sloping projections where rain water can accumulate and where there is little restraint to temperature and moisture movements. In these locations it is possible for the magnitude of the movements to exceed the strain capacity of any cementitious mortar and the use of more flexible elastomeric jointing may be required. Alternatively the members can be covered with a sheet membrane to prevent moisture penetration and salt attack.

Although repointing failures can occur as a result of the choice of an unsuitable mortar they can also result from unsatisfactory workmanship. Failure to clean the joint surfaces properly, too shallow a depth and insufficient compaction are common causes of adhesion problems. The depth of

the repointing should be at least 20 mm. The compacting tool should be narrow enough to penetrate into the joint. Where there are deep voids in the joints it might be necessary to insert a compressible backing rod behind the mortar to enable thorough compaction to be achieved.

7. DESALINATION

7.1 Flushing

Excessive and damaging salt concentration can be reduced in several ways. One method involves flushing the walls with water and requires repeated cycles of wetting and drying. The walls are wetted with fine mist sprays and allowed to dry before the wetting is repeated. Usually most of the salts tend to be concentrated close to the wall surfaces and the concentration levels diminish rapidly with increase in depth from the surface, Fig. 7. The duration of the wetting cycle will depend on the permeability of the masonry but it should not be excessive otherwise part of the salts will be moved deeper into the wall instead of being flushed out. In some instances it will be necessary to wet the wall for only 20 to 30 minutes. Similarly if drying proceeds too rapidly the drying front will penetrate too quickly into the masonry and much of the salt deposits will remain in the capillaries instead of being brought to the surface or close to it where they can either be brushed off or flushed away during the next wetting cycle. Flushing can produce a temporary acceleration of the rate of decay as a result of increased salt activity.

7.2 Poulticing

Another desalination treatment involves the application of a moist poultice of paper pulp or of an absorbent clay such as attapulgite. The absorbent nature of these materials helps to draw the salts out of the masonry, but again it is essential that the drying should take place slowly for an effective transfer of the salts from the masonry to the poultice. Too rapid drying can result also in cracking of the poultice and separation from the masonry.

The effectiveness of these treatments is monitored by periodic sampling of the masonry and the carrying out of salt analyses on drillings to establish whether a significant reduction in the levels of contamination has been achieved. It might be necessary to repeat the treatment a number of times.

7.2.1 Sacrificial Render. Continued fretting of exposed brick or stonework caused by salt attack has been prevented by covering the damaged walls with a sacrificial render. The render must be sufficiently permeable to allow the walls to breathe so that evaporation of moisture results in salts being transferred from the masonry to the render. The render will deteriorate and will eventually have to be replaced but the masonry will be protected from decay. Either a lime mortar (1:3 or 1:4 slaked lime:sand by volume) or a weak composition mortar (1:2:9 or 1:3:12 cement:lime:sand) can be used. The lime mortar is more absorbent than the composition mortar and will be easier to remove, but it might not be suitable in some external situations.

Where the walls were previously coated with relatively impervious paint or hard plaster, the replacement of the coating with a porous render may also help to reduce the level of dampness in the walls although it is unlikely to overcome a rising damp problem completely.

A sacrificial lime render was used to protect salt contaminated brickwork at St Mathews Church, Windsor NSW where, because of the thickness of the external

solid walls (370 to 1040 mm) and the presence in places of a rubble core, it was not feasible to insert a damp-proof course to overcome the rising damp problem. The church was built in 1820 with walls of sandstock bricks without damp-proof courses and salt attack associated with the rising damp has caused fretting of the external brickwork and damage to the internal plaster. In 1965 many of the decayed external bricks were replaced with sound sandstocks taken from another historic site but when the building was examined by EBS 7 years later, a number of the replaced bricks and some of the mortar showed severe decay, Fig. 8. In places the brick fretting had resulted in voids 40 mm deep. The rate of decay had been accelerated by the replacement of the original timber floor by a concrete slab which diverted additional sub-floor moisture into the walls.

Tests carried out by the CSIRO showed that the firing temperature of the bricks had been between 800°C and 900°C and the 24 hour cold water absorption was around 20 per cent. These factors would contribute to the poor resistance of the bricks to salt attack and their vulnerability to the disruptive forces associated with crystallisation and hydration.

Salt analyses of drillings taken from the damaged walls showed the presence of chlorides, sulphates and carbonates. The predominant salts were chlorides with a maximum concentration of 0.5 per cent.

It was decided as an interim protective measure to apply a sacrificial render over the damaged external brickwork to a height of about 1 m to draw the salts out of the walls and also to protect the brickwork against continued decay. A mixture of 1 part of slaked rock lime and 3 parts of sand was applied to the external walls to give a coating thickness of 20 mm. Internally the defective plaster was replaced with the same mix. A smooth internal finish was obtained by then applying a thin coat of 3 parts of lime to 1 part of sand followed by two coats of acrylic paint.

Periodic inspections have been made of the repairs since they were completed and after 4 years the internal surfaces are still in good condition. Externally there has been some localised decay of the render by salt attack which is in keeping with its sacrificial role and indicates that a transfer of salts is taking place, and the brickwork is being protected, Fig. 9. A sacrificial render was also applied to parts of the walls of the adjacent rectory (which is of similar construction to the church) with similar results.

It will be necessary to maintain the sacrificial render until a permanent solution is found for the rising damp problems but so far this has not proved onerous.

8. PROTECTIVE CHEMICAL TREATMENTS

The use of water repellents or consolidants to protect masonry against moisture penetration and salt attack should be considered with caution(5). In some instances they accelerate decay. Moisture might penetrate through the coating or enter the fabric through an untreated part of the building. Salt deposition and crystallisation can then occur near or at the interface between the treated and untreated zones and increased spalling or exfoliation follows. (An example is shown in Fig. 10 where a silicone coating was applied on the facade of an old sandstone building contaminated by salts). It might therefore be necessary to carry out a desalination treatment before these materials can be used. Laboratory and field trials on some protective treatments have shown

that with some kinds of masonry it is not possible to obtain sufficient penetration to provide effective protection against decay.

9. CONCLUSIONS

Dampness problems often arise from a combination of causes and it is essential to make a thorough inspection of the building so that a correct diagnosis can be made of the nature and cause of the trouble before carrying out remedial measures.

A number of methods of overcoming rising damp and salt attack have been discussed all of which have limitations. Some work well in certain situations but not in others. Where it is necessary to create a moisture barrier in the wall, the insertion of a damp proof course will provide a satisfactory solution to a rising-damp problem. But where there is damaging salt contamination, this treatment can exacerbate decay unless protective measures are taken to deal with the salt attack.

10. REFERENCES

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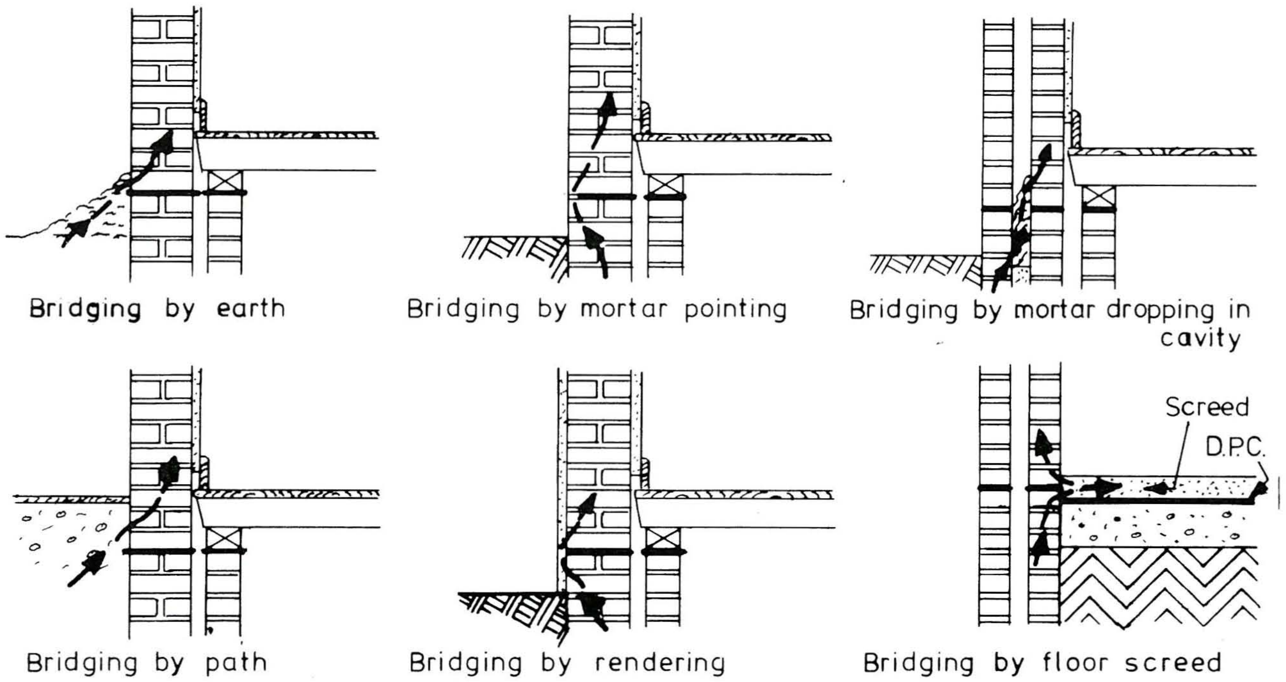

FIG. 1 BRIDGING OF DAMP-PROOF COURSE.
(From B.R.S. Digest 27.)

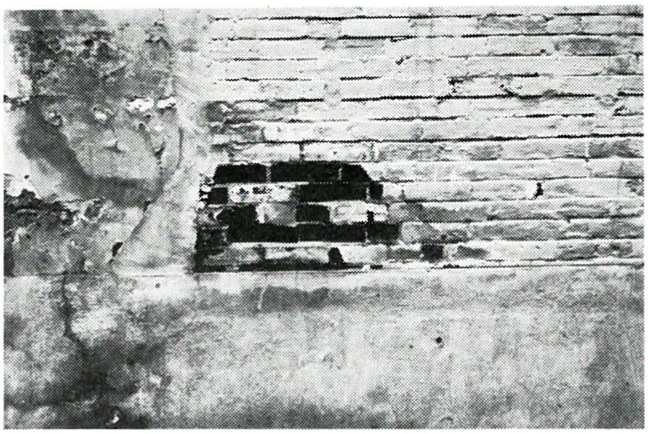

Fig. 2 Cement Render Diverted Salt Attack Higher

Fig. 3 Anhydrous Sodium Sulphate (300x)

Fig. 4 Hydrated Sodium Sulphate (300x)

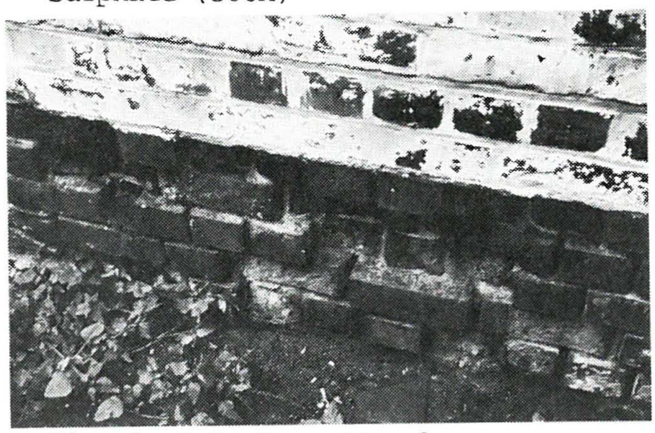

Fig. 5 Salt Damp Attack Below Damp-proof Course

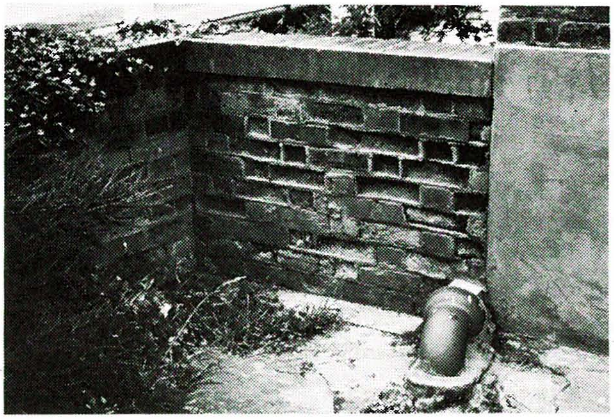

Fig. 6 Cement mortar contributed to sandstock decay

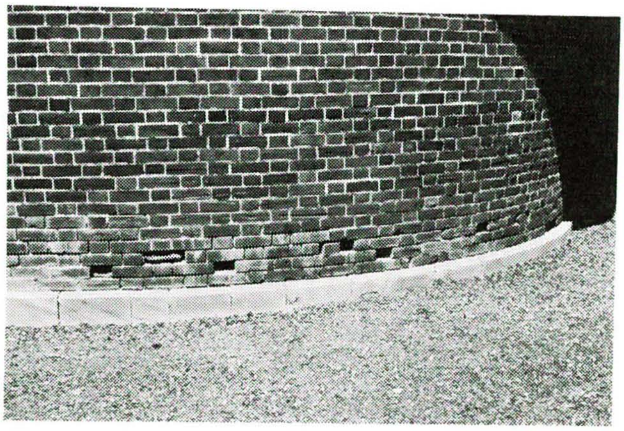

Fig. 8 Fretting Brickwork St Mathews Church.

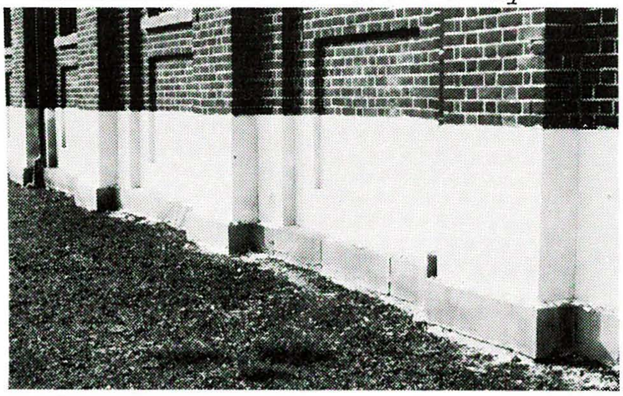

Fig. 9 Sacrificial Render after 4 years service

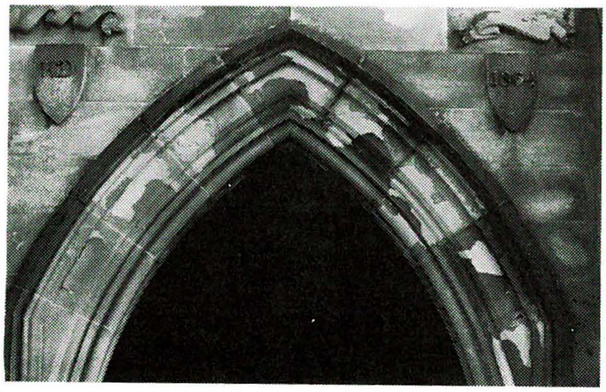

Fig. 10 Silicone caused accelerated exfoliation

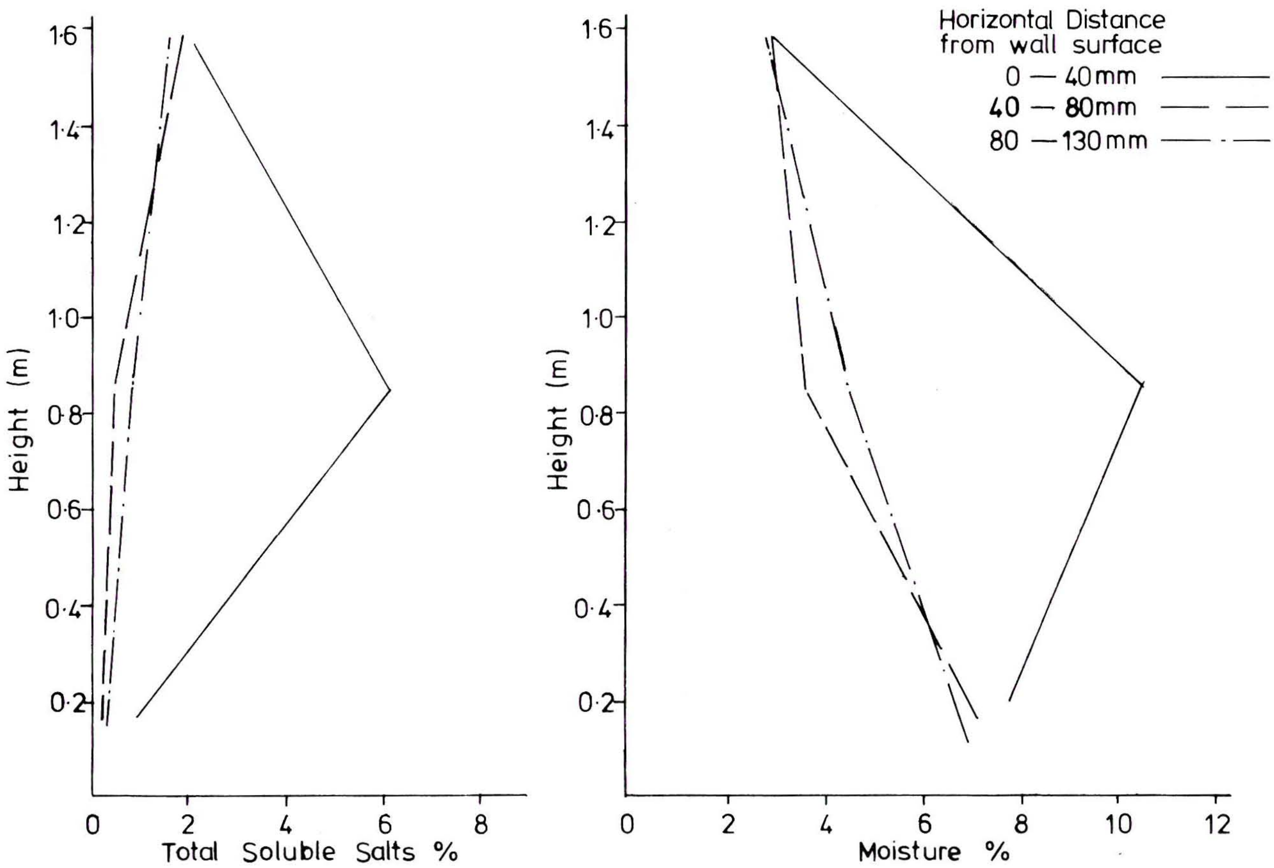

Fig 7 Salt and Moisture Distribution–Sandstone Wall.